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Review

Journey of kenaf in Malaysia: A Review

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Kenaf is an industrial crop with high potential for cultivation in a tropical climate. It is a source of raw material for fiber-based industries and paper production. Considerable research has been conducted to explore its adaptability and utilization in Malaysia since 2000, under the supervision of governmental and private organizations. A number of technologies and expertise among researchers have been developed to enhance kenaf production in Malaysia. However, international documentation of the research is limited, which is important for rectification to provide a comprehensive knowledge base for all tropical and subtropical countries. The main objective of this review is to provide an overview of the results of Malaysian research on kenaf. In addition, the past, present and likely future trends in kenaf research in Malaysia as a representative tropical region are summarized.

Key words: Industrial crop, tropical, agronomy, Kenaf

INTRODUCTION

The total area of Malaysia is about 328,600 km^2 of which Peninsular Malaysia is 131,600 km^2, Sabah is 73700 km^2 and Sarawak is 123,300 km^2. Peninsular Malaysia is separated from Sabah and Sarawak by 720 km (EAPAP, 1994). The Malaysian Agriculture is characterized by two distinct sectors, namely, the plantation sector and the smallholders' sector. Major crops planted are oil palm, rubber, rice, coconut and mixed horticulture. In addition, Malaysia is third largest exporter of timber in the world (Paridah et al., 2007).

Increased demand for timber industries ultimately has increased the rate of deforestation. About 76.3% of the land area of Malaysia was under forest in 2006, but declined to 62% in 2009 (Harun et al., 2009). Subsequently, deforestation will decrease the biodiversity of agricultural lands, which is detrimental for the environment and future improvement of crop.

To counter the issues of deforestation and biodiversity preservation, it is necessary to produce a non-wood crop that can fulfill the requirement for raw material from which

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paper and other products can be produced without causing destruction of forests and damage to environment.

Kenaf project in Malaysia was initiated way back in 1999 by the National Economic Action Council (NEAC) (Now known as National Economic Advisory Council) under the directive of YAB Prime Minister. NEAC formed a steering committee to study the potential of growing Kenaf in Malaysia as another industrial crop.

In early 2000, Malaysian Agricultural Research and Development Institute (MARDI) was directed by NEAC to co-ordinate a fast track research and development into the project. Since then, MARDI had successfully researched on variety screening, agronomic practices for Kenaf cultivation, harvesting and mechanization, retting, fiber processing, and some downstream applications such as animal feed and bio composite.

The Government has identified Kenaf as a potential crop (Extracts 1.1 and 1.2) to replace tobacco especially where the major tobacco growing areas are located. The ASEAN Free Trade Area or AFTA, which comes into effect in 2010, could result in lower prices and a reduction in import duties for tobacco. AFTA, to a certain extent, could negatively impact the competitiveness of Malaysian tobacco planters, whose cost of production is almost double compared with their peers in Thailand and Indonesia (Edeerozey et al., 2007; Mossello, 2010a).

Research on kenaf in Malaysia was initiated with evaluation of kenaf adaptability, identification of suitable cultivars for industrial and agriculture usage, agronomical management and inputs, end products and cost production in Malaysia (Asfaliza et al., 2001; Aminah et al., 2006; Ashori, 2006).

Presently, kenaf research focus on the production of biofuel, biocomposite materials and bio products (Aminah et al., 2004). The outcomes of kenaf research are of relevance for tropical countries in general, but the published Malaysian research on kenaf and its international accessibility are limited. The aim of this article is to provide a guideline for development of the kenaf industry in tropical regions. Subsequently, in this study, each area of kenaf research that has been considered in Malaysia will be discussed.

TAXONOMY AND MORPHOLOGY RESEARCCH OF KENAF IN MALAYSIA

Kenaf (*Hibiscus cannabinus*) is a herbaceous, annual, short-photoperiod plant that contains high-quality cellulose. The genus *Hibiscus* has a cosmopolitan distribution and contains more than 400 species. It is divided into six sections: *Furcaria*, *Alyogyne*, *Abelmoschus*, *Ketmia*, *Calyphylli* and *Azanzae*. Kenaf is classified in section *Furcaria*. The diversity in the number of chromosomes and genomes found in this section is unusual in the plant kingdom. Morphological and anatomical characters are helpful for selection of suitable kenaf genotypes for fiber and paper production. Kenaf has a large, light yellow, bell-shaped flower with a widely open corolla. The flowers are 8 to 10 cm in diameter with five petals (H'ng et al., 2009).

In 1999, the evaluation of kenaf adaptability to the tropical climate of Malaysia was the primary concern of scientists and agriculturists. In this regard, many experiments have been conducted on morphological and physiological traits and for selection of suitable germplasm accessions and cultivation locations. Moreover, to understand plant physiological requirements and phenomena, the morphology and anatomy of different kenaf cultivars have been evaluated. Studies of kenaf fiber morphology studies indicated significant differences in fiber diameter; length morphology exist among kenaf cultivars (H'ng et al., 2009; Abdul Khalil and Suraya, 2010). A similar distribution of vessels and tissues with longer fibers and thicker fiber cell walls were observed in all accessions (Figures 1 and 2). The differences in fiber morphology and quality are caused by genetic inheritance and manipulation, environmental factors, management practices and agricultural inputs (Hazandy et al., 2009; Hossain et al., 2011). The determined chemical composition of kenaf met the standard established by Pulp and Paper Industry of Malaysia (Edeerozey et al., 2007; Abdul Khalil and Suraya, 2010; Abdul Khalil et al., 2010). Research on modification of morphological traits is ongoing in Malaysia to utilize kenaf fiber more efficiently.

EVALUATION OF KENAF ADAPTIBILTY IN MALAYSIA

For successful commercial cultivation of kenaf, selection of a suitable genotype with high growth rates and biomass production is essential. Plant growth and biomass production are strictly related to their physiological characteristics. In a study of the gas exchange of three kenaf accessions, Guatemala 4, V36 and Kohn Kean 6, no significant differences in net photosynthesis rate were observed (Tahery et al., 2011). For the Malaysian tropical climate, the cultivars Everglade71, HC2, HC78, Thai kenaf, V36, and V133 were recommended as commercially suitable genotypes (Figure 3) (Asfaliza et al., 2001; Idris et al., 2001; Aminah, 2003; Aini et al., 2009; Hossain et al., 2011).

It was recommended from the results of a number of studies that photoperiod-insensitive and late-flowering cultivars were suitable for the tropical climate of Malaysia (Hossain et al., 2011; Wong et al., 2001; Daud, 2006). The highest yield to be reported (9.68 t/ha) was obtained from the accession V36. The kenaf cultivars available in Malaysia are: V4, V12, V25, V33, V34, V36, V40, V41, V43 and V72. An evaluation of the yield of two cultivars found that V132 produced 101.6 pods per plant with 19.6 seeds per pod, whereas V133 produced 199.2 pods per

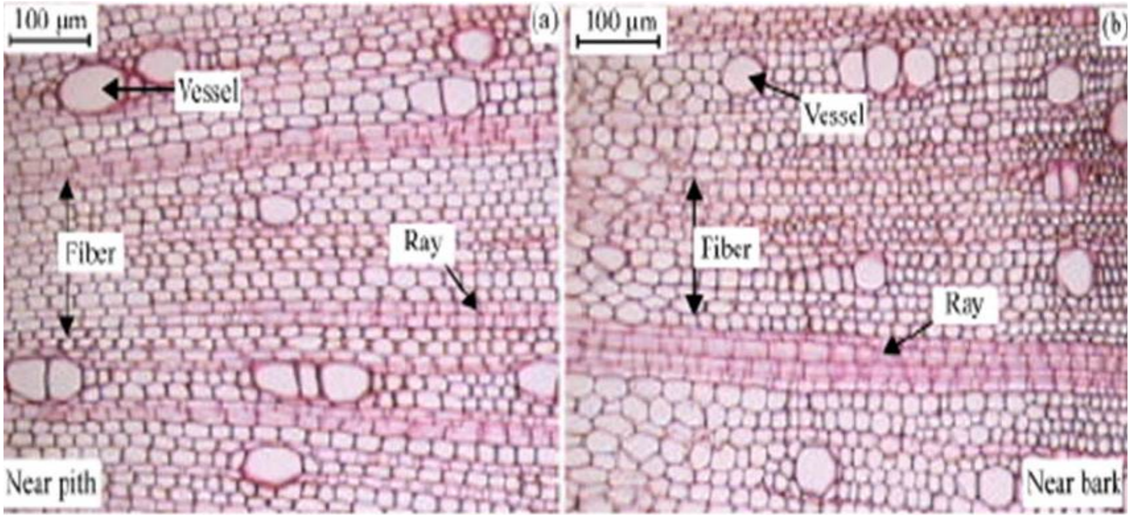

Figure 1. Cross section of kenaf near pith and bark (H'ng et al., 2010).

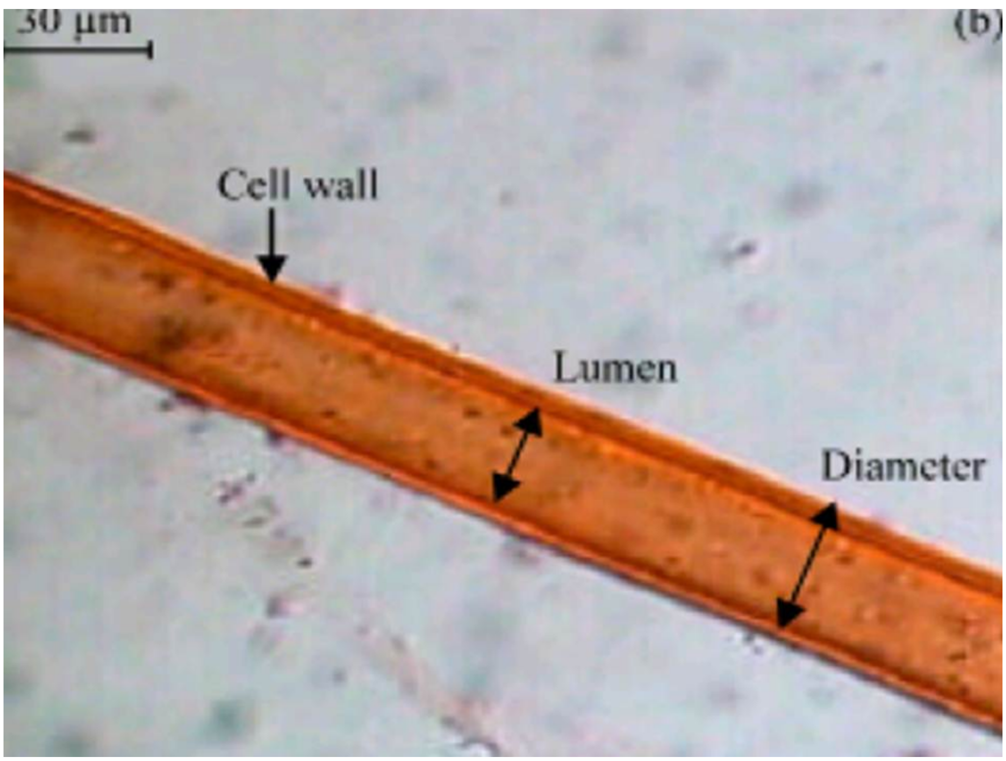

Figure 2. Core Fiber of kenaf microscopic image (H'ng et al., 2009).

plant with 20.4 seeds per pod (Asfaliza et al., 2001). Climatic factors can affect seed production of kenaf in Malaysia (Othman et al., 2006). Recently, HC2 and V133 were investigated as promising genotypes for seed forage and fiber production, especially on the BRIS soils of Malaysia (Aminah, 2003; Aminah et al., 2006; Aini et al., 2009; Hossain et al., 2011).

Kenaf cultivation on beach ridges interspersed with swales (BRIS)

The large scale production of kenaf was still hard to obtain because most of the recommended commercial production area (BRIS soils) was under tobacco cultivation. The National Kenaf and Tobacco Board

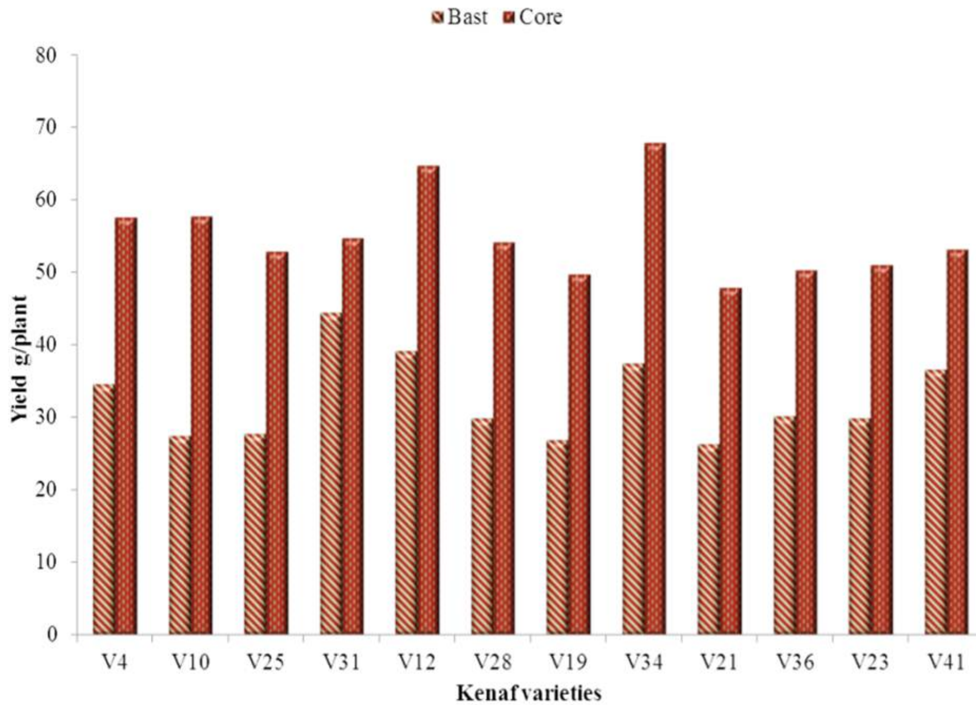

Figure 3. Dry matter yield of bast and core (g/plant) of 12 varieties harvested at 150 days in Malaysia (Daud, 2006).

planned the development of kenaf as an ecofriendly crop cultivation to replace the current tobacco production from BRIS soils by 2010 (Daud, 2006). The decision was made due to uncompetitive tobacco industry as compared to other countries and Tobacco Board has been instructed to undertake replacement of the tobacco by cultivating alternative crops according to their suitability. So, in 2006, the new research projects funded by National Kenaf and Tobacco Board (NKTB), Malaysian Timber Industry Board (MTIB), and Malaysian Agricultural Research and Development Institute (MARDI) and other related agencies and Ministries were approved on the cultivation of kenaf on BRIS soils (Aminah et al., 2006).

During the initial stage of this program, Kenaf was planted on BRIS soil specifically to replace tobacco through contracted farming method. Some BRIS areas were planted with Kenaf on different soil type in the area namely Kelantan and Terengganu.

Kenaf was reported to produce up to 15 tons/ha of stem production on fertile soils as oppose to 7 tons/ha on BRIS soil. It was concluded after a number of trials of Kenaf cultivation on BRIS that Kenaf is adapted to a wide range of soil types, but performs best on the fine to medium textured clay or loamy, well drained, fertile soils. Due to its high adaptability with all ranges of soils; Kenaf can be potentially planted on BRIS soil which is poor in water holding capacity and nutrient availability due to sandy texture in nature. Therefore these soils must be amended to produce higher yields. However, Kenaf can produce high productivity with the application of optimum fertilization and irrigation system (Alternatives Field Crops Manual, 1991).

Kenaf cultivation for seed production

Seed availability is a fundamental factor to ensure successful development of a novel crop. Insufficient and irregular supply of seed will obstruct planning and can cause setback to development of any industrial or agricultural project. To ensure seed availability to satisfy the strong industrial demand, many investigations of seed production and quality have been conducted. Many factors such as cultural practices, handling, harvesting, and environmental conditions can affect seed production.

In June 2000, the Malaysian Agriculture Research Development Institute (MARDI) initiated a research project on seed production at various locations in Malaysia to determine the most suitable climate and photoperiod for seed germination. The research established that temperature, rainfall and day length are important factors for kenaf flowering and seed production. In tropical countries such as Malaysia, the normal day length is 12 h and high humidity prevails for much of the year. Therefore, cultivation in the dry season is strongly recommended for seed production in tropical areas (Halimathul Saadiah, 2001; Halimathul Saadiah et al.,

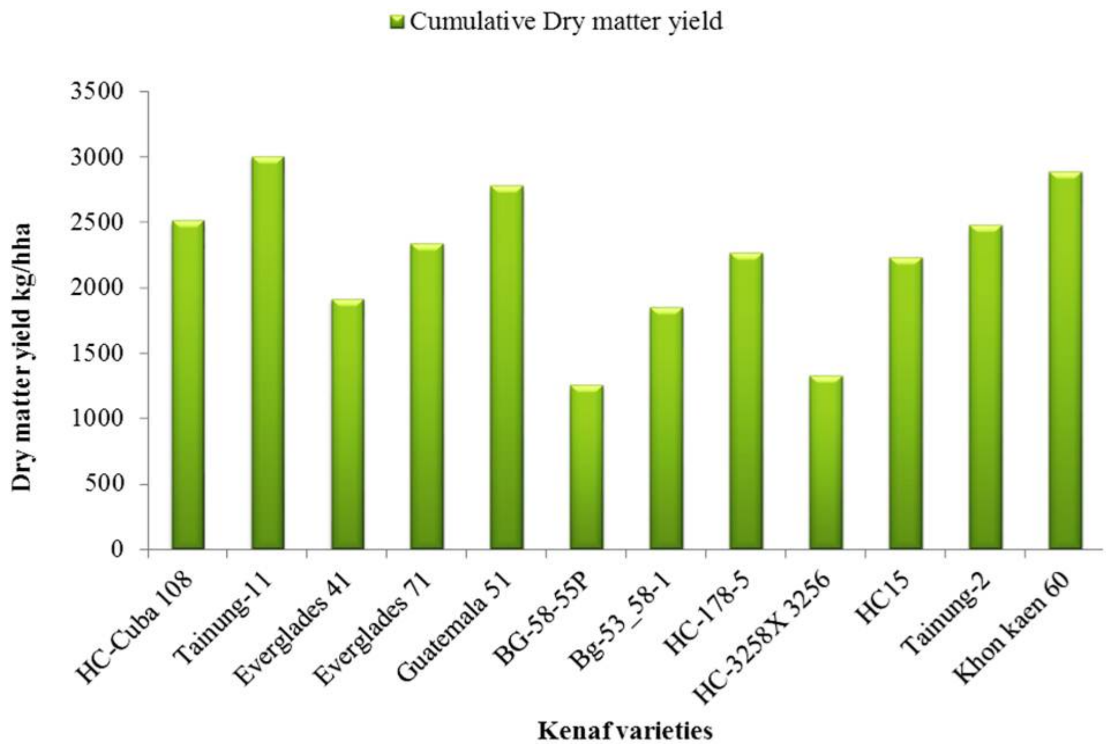

Figure 4. Mean dry matter yield of kenaf for forage production in Malaysia (Wong et al., 2001; Daud, 2006).

2006). The seeds require 60 to 90 days to mature after fertilization. The Plant Breeding Research Department of Malaysia has carried out research on kenaf hybridization techniques, but did not raise novel hybrids (Othman et al., 2006; Shukor et al., 2009). In addition, propagation from shoot apices and stem nodes has been investigated by various researchers and 70% plant survival was achieved after transplanting (Ayadi et al., 2011; Hossain et al., 2011a). An agronomic assessment of kenaf cultivars suggested that kenaf seed should be produced in the northern region of Malaysia because of the longer dry period (Halimathul Saadiah, 2001).

Kenaf cultivation for fiber production

Kenaf germplasm has been screened not only for seed production, but also evaluated for fiber production potential. Photosensitivity is the main factor that has a direct effect on kenaf growth and yield in Malaysia. Kenaf needs 12.5 h of daylight per day to flower. However, the Malaysian day is only 12 h long, which can result in the early flowering of some cultivars. Early flowering can reduce plant growth and fiber yield. Some studies have indicated that manipulation of agronomical practices and vegetative growth factors, such as planting and harvesting date, fertilizer type, pesticide application and planting density, can result in higher fiber yields of kenaf (Asfaliza et al., 2001; Idris et al., 2001; Aminah et al., 2004; Ashori et al., 2006; Othman et al., 2006; Wong et al., 2001). In most fiber production systems the final desirable plant production density was 185,000 to 370,000 plants/ha of single-stalked plants (Aminah et al., 2004). High population density could favor higher fiber yields, although the individual plant yield was higher with a lower population density (Aminah et al., 2004; Baldwin and Graham, 2006). The results of several studies of fiber yield showed that Malaysia can produce high yields of dry matter and fiber on an industrial scale (Halimathul Saadiah et al., 2006; Bai and Yu, 2011) (Figure 5). It was concluded that late-flowering and leafy cultivars are suitable for fiber and seed production, whereas early-flowering cultivars can be used as forage (Aminah et al., 2006; Raji, 2007; Wong et al., 2001). The screening of novel genotypes for seed and fiber production is ongoing in collaboration with researchers in China, Bangladesh and Malaysia under the UNIDO project (Aminah, 2003; Hossain et al., 2011a; Hossain et al., 2011b; Daud, 2006).

Kenaf cultivation for forage production

The results of growth and yield experiments on early-maturing cultivars conducted by MARDI indicated good potential for kenaf cultivation in Malaysia for forage use (Figure 4). Crude protein content of kenaf plants at four weeks after planting was 30.4%, which declined by up to

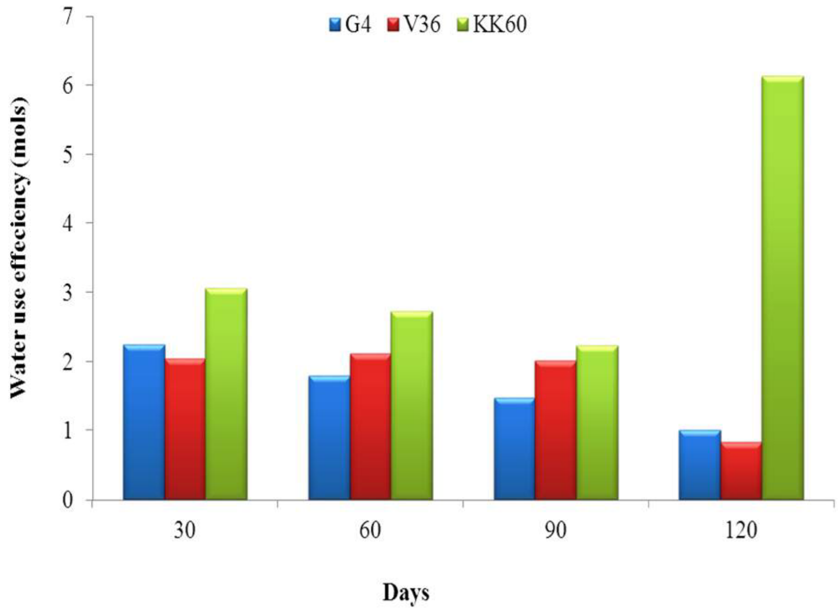

Figure 5. Water use efficiency of three kenaf varieties at different stages of growth (Tahery, 2011).

20% until the eighth week (Liang et al., 2003). Kenaf is considered to be a high-protein feed that is highly digestible (Aminah, 2003; Aminah et al., 2006). The feeding of ground and pelleted kenaf hay is encouraged as compared with chopped or whole plants. Furthermore, kenaf feed has positive effects on the growth, milk yield and milk quality of goats (Liang et al., 2003).

MANAGEMENT PRACTICES

Kenaf plant spacing and population

Kenaf production is highly dependent on climatic and agronomical factors, such as plant population density, irrigation, pest and insect management, and mechanization. Plant population density has a significant effect on kenaf production. Increased spacing (30 cm between rows and 5 cm between plants) of kenaf plants resulted in larger stems and a taller stand compared with more closely spaced plants. However, a higher population density tends to produce shorter stem stalks because of crowding effects. In contrast, kenaf stem core production was decreased at a low population density (Aminah, 2003; Aminah et al., 2004, 2006).

Water requirements

Research on the water requirements of kenaf revealed that plants need 12 mm of water per day for seed germination and initial crop establishment. The fiber quality and root length can be affected by fluctuation of the water table level. Kenaf plants can grow to a height of 3.2 m under an adequate water regime (Kassim, 2001; Tahery, 2011). The water requirements vary among cultivars at different developmental stages as a result of environmental factors (temperature and humidity) and physiological factors such as transpiration and photosynthesis (Tahery, 2011).

Weed and pest control

High humidity and rainfall during the growing season can result in fungal disease on kenaf crops. Kenaf is susceptible to fungal pathogens such as *Phytophthora*, nematode infestation, *Dysderus cingulatus*and *Aphis gossypii* Glover, which attacks seedlings 4 weeks after germination (Figure 6). These diseases and pests can damage young shoots, flower buds and developing fruits. Use of pesticides is crucial for plant protection (Aminah et al., 2006; Wong et al., 2001). The presence of a high population density of nematodes was reported in a number of field experiments on kenaf (Daud, 2006). Spray application of furadan to control nematodes is recommended after four weeks of germination (Daud, 2006).

Weed control is also essential for kenaf crop management. The critical period for weed control is during crop establishment. Pre-emergence herbicides could be used to control emerging weeds. The major weed species in the kenaf growing area are *Digitariaadscendens*, *Borreria alata*, *Cyperus rotundus*, *Cleome* sp., *Cynodon dactylon*, and *Calapogonium* sp. Flufenacet applied as a pre-emergence herbicide and fluazifop-butyl applied as an early post-emergence

Figure 6. Effects of disease and pest on kenaf (A) *Dysderus cingulatus* nymphs attack (B) phytopthora stem rot (Mardi, 2004).

herbicide are recommended by MARDI (Azmi, 2001). Bentazon was tested as a suitable late post-emergence herbicide for control of sedges and broadleaf weeds (Azmi, 2001). Limited information on pest and weed management is available; therefore there is a need to conduct additional studies on this aspect of kenaf production.

Nutrient requirements

The nutrient requirement of a crop is dependent on climatic conditions and soil properties. Kenaf is considered to be a nutrient-demanding crop. Previous research has investigated the effects of different levels of macronutrients. Different concentrations of nitrogen (N) fertilizer did not result in any significant differences in plant growth, biomass and foliage production (Figure 7) (Zainul and Mansur, 2001; Othman et al., 2006). However, application of N with phosphorus (P) at the rate of 100 N:200 P kg/ha showed significant positive effects on yield and growth of kenaf plants (Zainul, 2004). The recommended application rate for kenaf in Malaysia is 80 to 100 kg N/ha, 150 to 200 kg P/ha, and 100 kg K/ha (Hossain et al., 2011). Fiber production and quality were not affected by application of only N, whereas combined application of N and P showed small but non-significant effects (Daud, 2006).

The effects of different concentrations of organic carbon (C) on kenaf fiber quality and biomass production were determined by Hossain et al. (2011). Some significant effects on morphology and growth of kenaf were observed in response to 20 t C/ha, but high concentrations (more than 20 t/ha) reduced fiber production and quality (Hossain et al., 2011a). The nutrient requirements for kenaf production were found to vary among production areas because of variability in soil properties. Studies of kenaf cultivation on BRIS soils suggested an optimal N application rate of 300 kg N/ha (Othman et al., 2006).

The water regime and seasons are also important factors that affect kenaf yield responses to fertilizer concentrations. For example, application of N in wet seasons had a more significant effect than application during dry seasons (Aini et al., 2009; Hazandy et al., 2009). Use of organic manure such as chicken dung is also recommended for kenaf production on sandy and BRIS soils. Increases in forage yield by up to 27% have been reported by fertilizer optimization in various kenaf production trials conducted on BRIS soils in Malaysia (Aminah, 2003; Shukor et al., 2009; Hazandy et al., 2009; Hossain et al., 2011). However, there is a need for further detailed research on the fertilizer requirements of kenaf plants in different locations and soil types in Malaysia.

Mechanization

Harvesting is the most critical aspect of kenaf production. Manual harvesting of Kenaf is laborious and costly. Mechanized harvesting is more feasible and efficient for large-scale production. Many types of machines can be used for kenaf cultivation according to the uses of the end product. Furthermore, many modifications have been performed on different types of machines used for harvesting. For instance, a rice header, soybean thresher and some other types of threshers have been modified and successfully implemented in field trials by Malaysian engineers to develop a seed thresher for kenaf (Halimathul Saadiah et al., 2006; Ten et al., 2006; Ten and Wong, 2006; Ghahraei et al., 2011). For fiber production, a pedestrian-type kenaf stem cutter works satisfactorily, but has received very limited practical application in large plantations because of the low stem-cutting capacity of the machine. A sugar-cane tractor was used to harvest kenaf stems and showed good potential for large-scale kenaf plantations (Daud, 2006).

KENAF PROCESSING

After harvesting, kenaf is processed for a variety of uses, such as seed processing, forage and fiber production. For each of these end uses, different methods have been explored and adopted, as discussed below.

Kenaf seed processing and storage

Supply of high-quality seeds is needed for continuous and reliable kenaf production. However, seed production needs a particular climate and harvesting time. About 25% of kenaf seeds lose their viability because of suboptimal storage conditions. Kenaf seeds require drying for storage. It is necessary to clean and dry the seed thoroughly for successful long-term storage. Artificial dryers can be used for this purpose. The seed

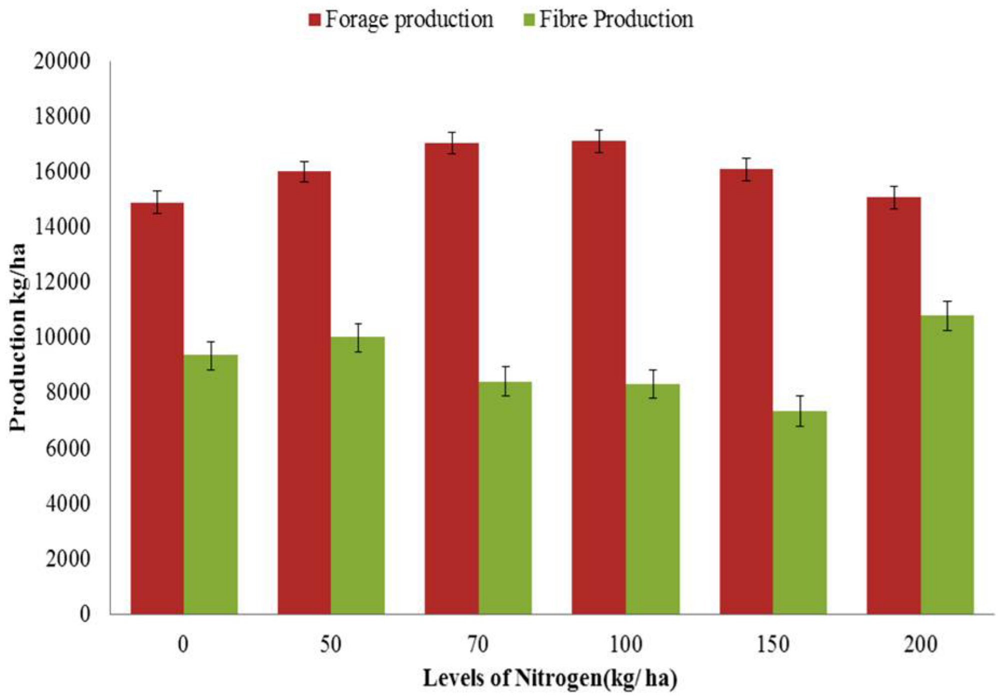

Figure 7. Effects of nitrogen level on forage and fiber production of kenaf (Zainal and Mansur, 2001).

can be stored at 8 to 12% moisture level. Several studies have indicated that seed should be stored at 5°C in a controlled humidity and temperature environment (Halimathul Saadiah, 2001; Bakhtiari et al., 2011).

Kenaf processing for forage use

As a high-protein feed source, kenaf is suggested to be suitable as a protein supplement for livestock feed. The optimum harvest interval for good-quality forage is about seven weeks to obtain the maximum dry yield. It is important to apply minimal doses of chemicals for production of crops to be used as animal feed. A multipurpose disc mill is needed to process kenaf material. The utility of a variety of forms of kenaf feed, such as pellets, silage, cubes, chaffs and meal, as animal feed have been studied (Liang et al., 2003). Kenaf meal is the most favorable for further processing because it can be mixed easily with other feed materials. Processing of kenaf involves a number of stages, such as harvesting, chopping and drying. On the basis of the results from a comprehensive study on forage production, it was recommended that forage kenaf should be harvested between 6 to 8 weeks after planting and chopped into 4-cm-long pieces and dried to less than 15% moisture. Kenaf meal should be stored in proper bags and in a dry environment. A study of bagging techniques revealed that kenaf meal can be stored for up to eight months in a plastic-lined bag at 21°C (Najib et al., 2001).

Kenaf processing for fiber production

As a fiber crop, the kenaf stem must be processed into the bast and core. Retting is the conventional method used to produce high-quality fiber. The traditional method is water retting, but this procedure results in severe environmental pollution and low-grade fiber; therefore it is essential to seek a pollution-free or minimal-pollution retting method. In a study of microbe retting, 91.31% removal of pectin was achieved under the optimal retting conditions. The most effective retting fungus was observed microscopically to be a type of epiphytic filamentous fungus (Yu and Yu, 2007). There is also demand for unprocessed kenaf stems from kenaf board manufacturers as an alternative woody species for paper production.

END PRODUCTS OF KENAF

Edible and cytotoxic oil

The kenaf oil content in kenaf seed varies on average between 16% and 22% (Bakhtiari et al., 2011). Kenaf seed oil is considered edible for human because of the high quantities of monounsaturated and polyunsaturated fatty acids (Coetzee et al., 2008). The seed oil is reported to be cytotoxic (Falusi, 2008) towards leukemia and cancer cells (Foo et al., 2011; Yazan et al., 2011a, b).

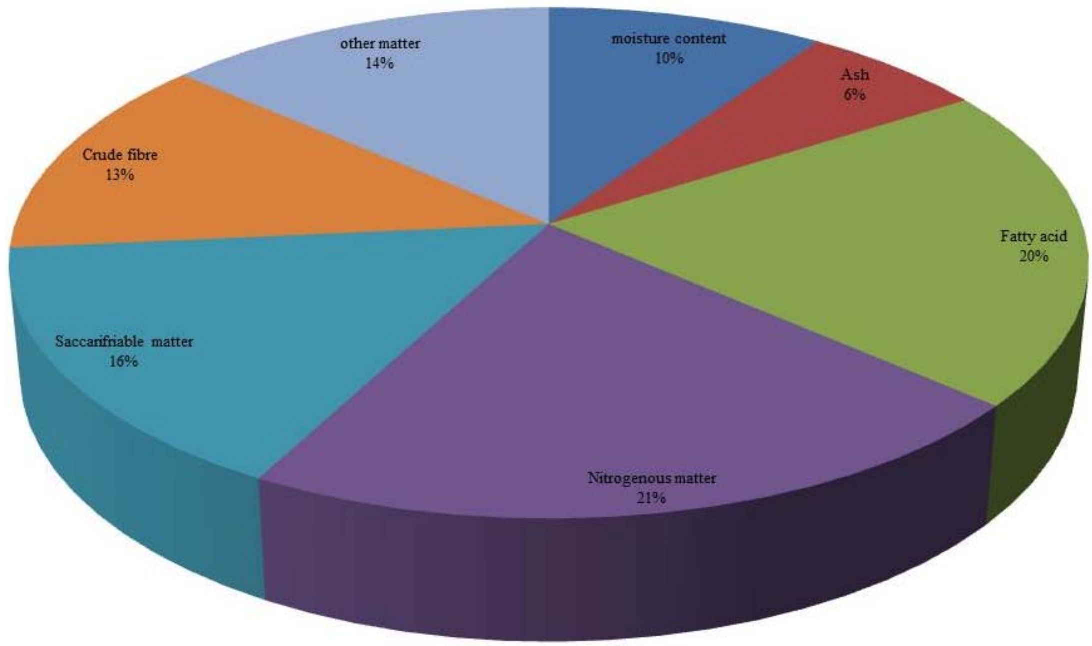

Figure 8. Composition of kenaf seed (Bakhtiari et al., 2011).

Kenaf stem parts were studied to investigate their biomedical value. A survey of pillows filled with kenaf decorticated fiber revealed that they had a positive effect on sleeping problems and reduced pains in 60% of respondents, which were selected on the basis of age, sex, marital status, and level of healthiness (Najib et al., 2006; Bakhtiari et al., 2011) (Figure 8).

Raw material for fiber

Kenaf fiber is a potential raw material for a variety of products such as reinforced composites, fiberboard, fabrics, high-quality paper, and furniture (Najib et al., 2006; Akil et al., 2011). The whole stem of kenaf is an attractive raw material that is suitable for use in high-quality paper production. Kenaf fibers exhibit different behavior during pulping and paper-making because of their different morphological structure (Aji et al., 2009; Akil et al., 2011; Mossello et al., 2010b). Fiber properties directly influence the pulping conditions applied in pulp and paper production. During refining, the core pulp rapidly attains a freeness value that is quite prohibitive for practical purposes. In contrast, bast pulp is refined easily and retains its strength (Mossello et al., 2010c; Harun et al., 2009). Because of differences in the quality of bast and core fibers, researchers have proposed fiber separation and pulping of each fraction separately, and using each pulp alone or blending the refined bast pulp and unrefined core based on the desired final product properties (Mossello et al., 2010d). Generally, selection of the pulping process depends on the function of the end product. Kraft, soda and soda-AQ processes are the most frequently used for kenaf. In comparison to Kraft pulping, the soda-AQ process gives a higher yield and better delignification without causing environmental damage because of restricted sulfur emissions. Soda-AQ pulping with kenaf whole stems requires a lower chemical input and produces a higher pulp yield than the soda process. In addition, the soda-AQ procedure is considered to be suitable for small-scale mills (Mossello et al., 2010, 2010e).

Biodegradable source of composite material

Kenaf has received attention from many researchers as a cheap, renewable, recyclable, and biodegradable alternative to synthetic polymers (Batchiar and Hamdan, 2009; Behjat et al., 2009; Ahmad et al., 2011). Kenaf exhibits a low density and non-abrasiveness during processing. Owing to kenaf's specific mechanical properties and biodegradability, after adequate treatment it can be used in combination with synthetic materials, such as polyester or rubber, which can help to greatly reduce the fiber hydrophilicity for the production of composite material (Ahmad et al., 2005, 2011; Aber et al., 2009; Abu Bakar et al., 2010). A number of studies have been carried out to explore the potential reinforcement of kenaf fiber with polymeric materials. A higher tensile strength of kenaf composite materials can be achieved by using fibers with higher tensile strength filling, but this could reduce the elasticity of kenaf fibers (Ahmad et al., 2005; Edeerozey et al., 2007; Aji et al., 2009, 2011). Different plant growth conditions can affect the length of kenaf fibers, which in turn affects the mechanical strength (Ochi, 2008). Some researchers disagree and state that modification of the fiber always improves the tensile strength of kenaf, but in fact sometimes the tensile strength is reduced (Kalam et al., 2005; Abdul Khalil and Suraya, 2010; Ismail et al., 2011; Thirmizir et al., 2011). The absorbent capacity of kenaf was found to be 10-fold more than the weight of kenaf core material (Najib et al., 2001, 2006; Cao et al., 2011; Jonoobi et al., 2011).

Use of kenaf fiber has shown promising results and requires further exploration to reduce environmental pollution. A number of research experiments have been conducted on the use of kenaf fiber, such as chemical treatment of fibers, matrix combinations, processing techniques, and environmental effects on the composite material. Most of these studies concluded that the problem of wettability of the composites inhibits further increase in fiber stuffing and, consequently, fiber pull-out (Ashori et al., 2005; Aber et al., 2009; Aji et al., 2009, 2011; Abdrahman and Zainudin, 2011).

Kenaf plants with long stems are reported to possess better fiber properties than plants with short stems. Determination of the critical length and tensile strength are important for preparation of a composite because, below this critical length, the mechanical and physical properties will be affected since strength and length of kenaf varies with fiber content (Ashori et al., 2006; Aji et al., 2011; Alavudeen et al., 2011; Anuar and Zuraida, 2011). For example, a composite can be damaged quite easily because of fiber pullouts. The critical fiber length for kenaf-fiber-reinforced biocomposites has been stated to be about 6 mm (Ashori, 2006; Abdul Khalil et al., 2010; Ibrahim et al., 2010; Bai and Yu, 2011). The results of a field experiment on the kenaf cultivar Everglades 71 indicated that the bast fiber contained a high content of holocellulose and alpha-cellulose, which could improve the composite strength and stability (Ashori, 2006; El-Shekeil et al., 2011). Morphological data for the same cultivar showed formation of a strong fiber–fiber hydrogen bond by virtue of easy pulp collapse. The longer length of the bast fibers resulted in flexible fibers that are good for fiber bonding, entanglement, and tear and tensile strength properties that are required in natural-fiber composites (Ashori, 2006; Talib et al., 2011). Similar results were obtained in the downstream sector of ongoing research at the Universiti Putra Malaysia on mechanical properties (Jonoobi et al., 2011; Harun et al., 2009). Many studies have shown considerable promise exists for the commercial viability and enhanced technological application of Malaysian cultivated kenaf for composite material production (Abdul Khalil et al., 2010; Abu Bakar et al., 2010; Abdrahman and Zainudin, 2011).

In a recent study kenaf was evaluated for phytoremediation of heavy-metal-contaminated soil. The results indicated that kenaf has potential to absorb and accumulate nickel and copper from contaminated soils (Hasfalina, 2010; Hasfalina et al., 2010). The detailed research is going on.

Status of kenaf in Malaysia

To develop the Kenaf industry in Malaysia requires an assessment of its overall business environment through a Strength, Weakness, and Opportunity and Threat (SWOT) analysis. There was a need to understand the various components and drivers of the industry in which it is competing. The information gained could then help support key decisions to be made in all areas including business development, Kenaf cultivation, and processing and manufacturing, production technology, human resource development, sales and marketing. It is then possible to make informed strategic choices and plan about the future of the organization. Development of kenaf industry in Malaysia has some considerable weak and strong aspects First of all, the climate of Malaysia is suitable for the kenaf cultivation. It has a high value as an added product and no waste plant utilization. The government and Research Departments of Malaysia are keenly interested in the cultivation of kenaf due to prospective market of its stem fiber in the region. However, unavailability of enough cultivation knowledge, lack of mechanization, high capital investment and low profits are main obstacles in developing kenaf industry in Malaysia.

According to a survey conducted in 2009 by ECER, available opportunities related to kenaf production has been revealed. They reported that there is high demand for Kenaf fibers both locally and internationally which should create opportunity for Kenaf stem cultivation. Kenaf stems market is promising as the demand is increasing. Currently, Kenaf stems have been produced by NKTB, *Everise crimson* and KFI. For example, there is a monthly demand from *Panasonic Electric Work Kenaf (Malaysia) Sdn Bhd* by 900 tonnes through NKTB. There is also a demand on Kenaf fiber and core locally and internationally. Locally, there is a willingness of companies such as *The Armour Factory* to be involved in this procuring of Kenaf fiber to replace their current material to Kenaf hybrid. Internationally, *KEFI Italy* has indicated interest to purchase 12,000 tonnes per year.

There are a number of research institutions (that is, UPM, MARDI and FRIM) who are continuously carrying out research for the development of Kenaf industry. For example, UPM is currently undertaking “Downstream Research and Marketing on Kenaf Based Products” funded by *Economic Planning Unit* (EPU), “Increased Production, Efficiency in Small-Holder Kenaf Production Systems for Specific Industrial Applications”, funded by UNIDO and other research projects which are funded by the university, and MARDI which was directed by NEAC to coordinate R&D on Kenaf as another industrial crop

(Including research on the upstream); and FRIM is developing a product, *Oriented Strand Board* (OSB) by using Kenaf bark. With this condition, there should be an increment in top down R&D funding from the government on selected area according to the Road Map.

It has become a national agenda as the Government supports the promotion of Kenaf as seventh commodity. In 2010, NKTB has received an allocation of more than RM 30 million for developing Kenaf industry in the states of Terengganu, Pahang and Kelantan under seven (7) key programs of Kenaf. This shows a commitment from government in supporting the Kenaf industry, e.g.: Optimization and reproduction of necessary harvesting and fiber processing machines.

FUTURE STRATEGIES

1. Local seed production, cultivation and harvesting of Kenaf and grading of fiber are still ineffective and a there is need to conduct research on these issues.
2. Farmers require effective extension and guides to improve their cultivation agronomy and raise yield. For this to happen, human resource development has to be enhanced to meet farmers' needs.
3. Existence of opportunities is necessary for high value added processing and innovation if fiber supplies arrangement tackled.
4. Government support and participation continue to be an important driver to Kenaf initiative.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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REFERENCES

Abdrahman MF, Zainudin ES (2011). Properties of kenaf filled unplasticized polyvinyl chloride composites. In: Key Eng. Mater. pp. 507-512.

Abdul Khalil HPS, Suraya NL (2010). Anhydride modification of cultivated kenaf bast fibers: Morphological, spectroscopic, and thermal studies. BioResource 6(2):1122-1135.

Abdul Khalil HPS, Yusra AFI, Bhat AH, Jawaid M (2010). Cell wall ultrastructure, anatomy, lignin distribution, and chemical composition of Malaysian cultivated kenaf fiber. Ind. Crops Prod. 31(1):113-121. http://dx.doi.org/10.1016/j.indcrop.2009.09.008

Aber S, Khataee A, Sheydaei M (2009). Optimization of activated carbon fiber preparation from kenaf using K2HPO4 as chemical activator for adsorption of phenolic compounds. Bioresour. Technol. 100(24):6586-6591.http://dx.doi.org/10.1016/j.biortech.2009.07.074; PMid:19692238

Abu Baker, MA, Ahmad S, Kuntjoro W (2010). The mechanical properties of treated and untreated kenaf fibre reinforced epoxy composite. J. Bio. Based Mater. Bioenergy 4(2):159-163. http://dx.doi.org/10.1166/jbmb.2010.1080

Ahmad SH, Anuar H, Rased R, Zakaria S, Sameni JK, Mohd Amin MN, Omar O, Hassan K, Al-Asraf Z (2005). Kenaf fibers reinforced thermoplastics natural rubber composites. In: Appita Annual Conference. pp. 21-26.

Ahmad SH, Rasid R, Bonnia NN, Zainol I, Mamun AA, Bledzki AK, Beg MDH(2011). Polyester-kenaf composites: Effects of alkali fiber treatment and toughening of matrix using liquid natural rubber. J. Compos. Mater. 45(2):203-217. http://dx.doi.org/10.1177/0021998310373514

Aini NAS, Hamzah MB, Hazandy AH, Ghizan S, Fadzhel MMN (2009). Growth and phenology of kenaf (Hibiscus cannabinus l.) varieties. Pertanika J. Trop. Agric. Sci. 32:29-33.

Aji IS, Sapuan SM, Zainudin ES, Abdan K (2009). Kenaf fibres as reinforcement for polymeric composites: A review. Int. J. Mech. Mater. Eng. 4(3):239-248.

Aji IS, Zainudin ES, Khalina A, Sapuan SM (2011). Effect of fibre size and fibre loading on tensile properties of hybridized kenaf/palf reinforced hdpe composite. In: Key Eng. Mater. pp. 680-685.

Akil HM, Omar MF, Mazuki AAM, Safiee S, Ishak ZAM, Abu Bakar A (2011). Kenaf fiber reinforced composites: A review. Mater. Des. 32(8-9):4107-4121. http://dx.doi.org/10.1016/j.matdes.2011.04.008

Alavudeen A, Thiruchitrambalam M, VenkateshwaranN, Elayaperumal A, Athijayamani A (2011). Improving mechanical properties of eco-friendly polymer hybrid composites. Int. J. Performabil. Eng. 7(2):172-178.

Aminah A (2003). Forage and fiber production of selected kenaf introductions on bris. In: Second technical review meeting on the national Kenaf Research project. MARDI. Malaysian Agriculture Institute (MARDI), SERDANG, p. 146.

Aminah A, Wong CC, Hasim I (2004). Kenaf fiber production as affected by plant population and plant age on bris soil. In: Third technical review meeting on the national Kenaf Research project. MARDI, pp. 9-16.

Aminah A, Wong CC, Hasim I (2006). Production potential of kenaf for forage and fiber on bris under smallholder production system. In: Fourth technical review meeting on the National Kenaf Research Project, MARDI, pp. 15-20.

Anuar H, Zuraida A (2011). Improvement in mechanical properties of reinforced thermoplastic elastomer composite with kenaf bast fibre. Compos. Part B: Eng. 42(3):462-465. http://dx.doi.org/10.1016/j.compositesb.2010.12.013

Asfaliza R, Mansur P, Ghawas MM, Wong CC (2001). Assessment of kenaf germplasm accessions for their adaptability to the Malaysian environment. In: First technical review meeting on the national Kenaf Research project. Malaysian Agriculture Research Institute (MARDI), Serdang Malaysia, pp. 13-24.

Ashori A (2006). Pulp and paper from kenaf bast fibers. Fiber. Polym. 7(1):26-29.

Ashori A, Harun J, Raverty W, Yusoff MNM (2006). Chemical and morphological characteristics of Malaysian cultivated kenaf (Hibiscus cannabinus) fiber. Polym. - Plast. Technol. Eng. 45(1):131-134. http://dx.doi.org/10.1080/03602550500373782

Ashori A, J. Harun, Raverty WD, Wan MZ, Nor M (2005). Effect of chitosan addition on the surface properties of kenaf (Hibiscus cannabinus) paper. Iran. Polym. J. (English Edition) 14(9):807-814.

Ayadi R, Hamrouni L, Hanana M, Bouzid S, Trifi M, Khouja ML (2011). In vitro propagation and regeneration of an industrial plant kenaf (Hibiscus cannabinus L). Ind. Crops Prod. 33(2):474-480. http://dx.doi.org/10.1016/j.indcrop.2010.10.025

Azmi M (2001). Weed control in kenaf. In: First technical review meeting on the National Kenaf Research Project. MARDI, SERDANG, pp. 42-56.

Bai LH, Yu HQ (2011). Study on properties of bast fibers. In: Adv. Mater. Res. pp. 1989-1992. PMid:21806976

Bakhtiari MR, Ahmad D, Othman J, Ismail N (2011). Physical and

mechanical properties of kenaf seed. Appl. Eng. Agric. 27(2):263-268. http://dx.doi.org/10.13031/2013.36480
Baldwin BS, Graham JW (2006). Population density and row spacing effects on dry matter yield and bark content of kenaf (Hibiscus cannabinus L.). Ind. Crops Prod. 23(3):244-248. http://dx.doi.org/10.1016/j.indcrop.2005.06.005
Batchiar DS, Hamdan SM (2009). The influence of alkaline surface fibre treatment on the impact properties of sugar palm fibre-reinforced epoxy composites. Polym.-Plast. Technol. Eng, 48:379-389. http://dx.doi.org/10.1080/03602550902725373
Behjat T, Russly AR, Luqman CA, Yus AY Nor Azowa I (2009). Effect of peg on the biodegradability studies of kenaf cellulose -polyethylene composites. Int. Food Res. J. 16(2):243-247.
Cao XV, Ismail H, Rashid AA, Takeichi, T, Vo-Huu T (2011). Mechanical properties and water absorption of kenaf powder filled recycled high density polyethylene/natural rubber biocomposites using mape as a compatibilizer. BioResour. 6(3):3260-3271.
Coetzee R, Labuschagne MT, Hugo A (2008). Fatty acid and oil variation in seed from kenaf (Hibiscus cannabinus L.). Ind. Crops Prod. 27(1):104-109. http://dx.doi.org/10.1016/j.indcrop.2007.08.005
Daud MDM (2006). Development of kenaf production in Malaysia. In: Fourth technical review meeting on the National Kenaf Research project. MARDI, pp. 119-130.
Edeerozey AMM, HM Akil, Azhar AB, Ariffin MIZ (2007). Chemical modification of kenaf fibers. Mater. Lett. 61(10):2023-2025.
http://dx.doi.org/10.1016/j.matlet.2006.08.006
El-Shekeil YA, Sapuan SM, Zainudin ES, Abdan K (2011). Optimizing processing parameters and fiber size for kenaf fiber reinforced thermoplastic polyurethane composite. In: Key Eng. Mater. pp. 297-302.
Falusi OA (2008). Inheritance of characters in kenaf (Hibiscus cannabinus). Afr. J. Biotechnol. 7(7):904-906.
Foo JB, Yazan LS, Chan KW, Tahir PM, Ismail M (2011). Kenaf seed oil from supercritical carbon dioxide fluid extraction induced g1 phase cell cycle arrest and apoptosis in leukemia cells. Afr. J. Biotechnol. 10(27):5389-5397.
Ghahraei O, Ahmad D, Khalina A, Suryanto H, Othman J (2011). Cutting tests of kenaf stems. Trans. ASABE 54(1):51-56. http://dx.doi.org/10.13031/2013.36252
H'ng PS, Khor BN, Tadashi N, Aini ASN, Paridah MT (2009). Anatomical structure and morphology of new kenaf varieties. Asian J. Sci. Res. 2(3):161-166. http://dx.doi.org/10.3923/ajsr.2009.161.166
Halimathul Saadiah AS, Wahab Nafis A, Daud AH, Hajazi AM (2006). Commercial kenaf seed production to meet market demand for the kenaf industry. In: The fourth Technical Review Meeting on research and development of Kenaf Production for Animal Feed and Fibre, M. D. Mohd., Daud abdullah Othman and W. C. Chee (Eds.). Malaysian Agriculture Research Institute (MARDI), Pahang, pp. 32-38.
Halimathul Saadiah AS (2001). Report on seed production of selected germeplasm accession: Seed quality and storage conditions. In: First technical Review meeting on the national kenaf research project. Malaysian Agriculture Research Institute, Serdang: pp. 2-5.
Harun J, Paridah Md T, Khalina A (2009). Kenaf- Its establishment and journey towards energizing the wood-based and biocomposite industry in Malaysia. In: International Conference on Prospect of Jute and Kenaf as Natural Fibres, Dhaka-Bangladesh.
Hasfalina CM, Maryam RZ, Luqman CA, Rashid M (2010). The potential use of kenaf as a bioadsorbent for the removal of copper and nickel from single and binary aqueous solution. J. Nat. Fibers 7(4):267-275. http://dx.doi.org/10.1080/15440478.2010.527508
Hazandy AH, Hazimy MY, Aini NAS, Bahrum M, Hanafi MM (2009). Effects of different fertilizer application level on growth and physiology of hibiscus cannabinus l. (kenaf) planted on bris soil. J. Agric. Sci. 1(1):121-127.
Hossain MD, Hanafi MM, Jol H, Hazandy AH (2011a). Growth, yield and fiber morphology of kenaf (hibiscus cannabinus l.) grown on sandy
bris soil as influenced by different levels of carbon. Afr. J. Biotechnol. 10(50):10087-10094.
Hossain MD, Hanafi MM, Jol H, Jamal T (2011b). Dry matter and nutrient partitioning of kenaf (hibiscus cannabinus L.) varieties grown on sandy bris soil. Austral. J. Crop Sci. 5(6):654-659.
Ibrahim NA, W Md Zin Wan Yunus, Othman M, K Abdan, Hadithon KA (2010). Poly(lactic acid) (pla)-reinforced kenaf bast fiber composites: The effect of triacetin. J. Reinfor.Plast. Composit. 29(7):1099-1111. http://dx.doi.org/10.1177/0731684409344651
Idris ABGK, Chin FY, Wong CC (2001). Preliminary studies on kenaf ssed production at sintok farm, kedah.Proceeding. In: First technical review meeting on the National Kenaf Research project. MARDI, pp. 6-10.
Ismail H, Abdullah AH, Bakar AA (2011). Influence of acetylation on the tensile properties, water absorption, and thermal stability of (high-density polyethylene)/(soya powder)/(kenaf core) composites. J. Vinyl Addit. Technol. 17(2):132-137. http://dx.doi.org/10.1002/vnl.20262
Jonoobi M, Harun J, Tahir PM, Shakeri A, Saifulazry S, Makinejad MD (2011). Physicochemical characterization of pulp and nanofibers from kenaf stem. Mater. Lett. 65(7):1098-1100. http://dx.doi.org/10.1016/j.matlet.2010.08.054
Kalam A, Sahari BB, Khalid YA, Wong SV (2005). Fatigue behavior of oil palm fruit bunch fibre=epoxy and carbon fibre=epoxy composites. Compos. Struct. 71(1):34-44. http://dx.doi.org/10.1016/j.compstruct.2004.09.034
Kassim B (2001). Water management requirement for kenaf production in Malaysia In: First technical review meeting on the National Kenaf Research project. MARDI: pp. 37-41.
Liang JB, Paengkoum P, Chuntiratikul A (2003). Potential of kenaf as protien forage for ruminant livestock. In: Proceeding of the second techncal review meeting on research and development of kenaf production for animal feed and fibre, C. C. Wong and M. D. Mat Daham (Eds.). Malaysian Agriculture Research Institute, Serdang, pp. 74-80.
PMid:12601570
Mossello AA, Harun J, Tahir PM, Hossein R, Ibrahim R, Shamsi SRF, Ainun ZM (2010a). A review of literatures related of using kenaf for pulp production (beating, fractioation and recycled fiber). Mod. Appl. Sci. 4(9):21-29. http://dx.doi.org/10.5539/mas.v4n9p21
Mossello AA, Harun J, Ibrahim R, Resalati H, Shamsi SRF, Tahir PM, Yusoff MNM (2010b). Evaluation of linerboard properties from Malaysian cultivated kenaf soda-anthraquinone pulps versus commercial pulps. BioResour. 5(3):1595-1604.
Mossello AA, Harun J, Resalati H, Ibrahim R, Shmas SRF, Tahir P.M (2010c). New approach to use of kenaf for paper and paperboard production. BioResource 5(4):2112-2122.
Mossello AA, Harun J, Resalati H, Ibrahim R, Tahir PM, Shamsi SRF, Mohame AZD (2010d). Soda-anthraquinone pulp from Malaysian cultivated kenaf for linerboard production. BioResource 5(3):1542-1553.
Mossello, AA, Harun J, Tahir PM (2010e). A review of literatures related of using kenaf for pulp production (beating, fractionation, and recycled fiber). Mod. Appl. Sci. 4(9).
Najib M, Wan MAM, Zahari R, Sukri M, Yunus I (2006). Status of kenaf product development: Processing, animal feed, biofiber and pharmaceutical properties. In: Fourth technical review meeting on the National Kenaf Research project Malaysian Agriculture Research Institute (MARDI), pp. 42-59.
Najib MAM, Hamdan A, Ismawaty N (2001). Processing and handling technology of kenaf (hibiscus cannabinus l.) production in Malaysia. In: First technical review meeting on the National Kenaf Research project MARDI, SERDANG, pp. 70-73.
Ochi S (2008). Mechanical properties of kenaf fibers and kenaf/pla composites. Mech. Mater. 40(4-5):446-452. http://dx.doi.org/10.1016/j.mechmat.2007.10.006
Othman A, Wong CC, Zainul AH, Atta AAM, Kassim B, Hamid A (2006). Consolidation of production technologies for commercialization of kenaf cultivation in Malaysia. In: Fourth technical review meeting on the National Kenaf Research project. MARDI, pp. 3-13.
Raji JA (2007). Intercropping kenaf and cowpea. Afr. J. Biotechnol. 6(24):2807-2809.
Shukor NAA, Hamzah MB, Hamid HA, Salleh G, Nasir MFM (2009).
Growth and phenology of kenaf (Hibiscus cannabinus L.) varieties. Pertanika J. Trop. Agric. Sci. 32(1):29-33.
Tahery Y (2011). Comparative water relation of three varieties of Hibiscus cannabinus L. (kenaf). Afr. J. Biotechnol. 10(63):13797-13801.
Tahery Y, Abdul-Hamid H, Tahery E, Deljoo E, Mogrilan M (2011).

Comparative photosynthesis and transpiration of three varieties of hibiscus cannabinus L. (kenaf). Afr. J. Agric. Res. 6(8):2010-2014.

Talib RA, Tawakkal ISMA, Abdan K (2011). The influence of mercerised kenaf fibres reinforced polylactic acid composites on dynamic mechanical analysis. In: Key Eng. Mater. pp. 815-820.

Ten S, Wong CC, Saadiah HAS (2006). Mechanization status on commercial kenaf seed thresher for small holders. In: Fourth technical review meeting on the national Kenaf Research project. MARDI, pp. 71-73.

Ten ST, Wong CC (2006). Design and development of kenaf seed thresher machine for seed production under rainshelter. In: Acta Hortic. pp. 245-249.

Thirmizir MZA, Ishak ZAM, Taib RM, Rahim S, Jani SM (2011). Kenaf-bast-fiber-filled biodegradable poly(butylene succinate) composites: Effects of fiber loading, fiber length, and maleated poly(butylene succinate) on the flexural and impact properties. J. Appl. Polym. Sci. 122(5):3055-3063. http://dx.doi.org/10.1002/app.34046

Wong CC, Nizam AM, S Vijaysegaran, Mah SY, Ghawas M (2001). Kenaf germplasm introductions and assessment of their adaptability in Malaysia for forage production. In: First technical review meeting on the National Kenaf Research project. MARDI, pp. 13-24.

Yazan LS, Foo JB, Chan KW, Tahir PM, Ismail M (2011a). Kenaf seed oil from supercritical carbon dioxide fluid extraction shows cytotoxic effects towards various cancer cell lines. Afr. J. Biotechnol. 10(27):5381-5388.

Yazan LS, Foo JB, Chan KW, Tahir PM, Ismail M (2011b). Effect of kenaf seed oil from different ways of extraction towards ovarian cancer cells. Food Bioprod. Process. 89(4):328-332. http://dx.doi.org/10.1016/j.fbp.2010.10.007

Yu H, Yu C (2007). Study on microbe retting of kenaf fiber. Enzyme Microb. Technol. 40(7):1806-1809. http://dx.doi.org/10.1016/j.enzmictec.2007.02.018

Zainul ABH (2004). Nutrient requirements of kenaf for forage and fiber production: Effect of potassium on growth and yield. In: Third technical review meeting on the National Kenaf Research project. . MARDI, Serdang, pp. 41-47.

Zainul ABH, Mansur P (2001). Nutrient requirement of kenaf for forage and fiber production. In: First technical review meeting on the National Kenaf Research project, MARDI, pp. 30-36.