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Review

Kenaf Is the Key to Go Green in the Era of Environmental Crisis: A Review

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Abstract - Ecologically sustainable means of development is the point to support environmental homeostasis. One of our roles is to find bio-degradable resources that can be substituted for petroleum-based products to effectively abide by the natural viability. To counter the issues of deforestation and preserve biodiversity, it is necessary to produce a non-wood crop that can fulfill the requirement for raw material from which several products can be produced. Kenaf (*Hibiscus cannabinus*), a member of the family Malvaceae, is showing sufficient potentiality along this road-map. Due to its rich fiber content, it has been used extensively in various fields for long, probably as early as 4,000 BC. At present, kenaf has been used as provider of paper, plastics, fiber glass, biofuel, activated carbon and epoxy composite. This obviously catch one's attention towards its capability to replace petroleum-based products as a whole. Moreover, the plant shows considerable relevance in decreasing pollutants by virtue of its enormous absorption capacity. These multiple applications of kenaf justify its credibility to be the best resource for the better world. The paper presents an overview on its numerous uses reported in the literature that we have investigated and its great potential as a valuable multipurpose crop.

Key words − Bio-degradable, Bioplastic, Kenaf, Sustainable development

Introduction

What alternatives do we need to alleviate the environmental crisis?

One of our era's greatest scourges is environmental pollution, on account not only of its impact on climate change but also its impact on public and individual health due to increasing morbidity and mortality. Like these days, when pollution reaches a peak, a proper means should be urgently employed to mitigate the very causes that have culminated into the present detriment. A paramount agent causing excessive environmental pollution constitutes the non-biodegradable wastes derived from synthetics used in manufacturing diverse modern-day utilities. These mainly include plastics and fiber glass that get accumulated in the environment, when being left out. In this regard, it is necessary to develop sustainable alternatives of these hazardous pollutants. Kenaf, *Hibiscus cannabinus* L, would be the solution that we look for. Kenaf is a plant that most people may not have heard about but is used to produce many types of eco-friendly materials. It is mostly found in temperate and tropical regions (Saba *et al*., 2015). The ancient Egyptians used its fibers to make the sails for their ships. Since the 1960s, Korea recognizes it as the promising non-wood fiber for gunny sack production. However, it has limited use. In recent years, its value in Korea has been increasing as it has been partly used as forage. Such important uses could significantly increase the economic value of this crop. In this review, we highlighted properties of industrial kenaf that could be an important crop with many complementary uses in the environmental pollution era.

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Results and Discussion

History

Kenaf is probably originated in sub-Saharan Africa and has been primarily used as cordage crop and secondarily as a livestock feed for over 6000 years (Dempsey, 1975a). Kenaf is a good source of raw material fiber for pulp, paper and other fiber products. It was first domesticated in northern Africa, including its introduction to India 200 years ago, to

Russia in 1902, to China in 1935, and to the U.S.A in the 1940's during World War II (Dempsey, 1975a; Alexopoulou and Monti, 2013). In the early1970s, kenaf was first introduced in Malaysia and it was highlighted in the late 1990s as an alternative material for producing products such as fiberboard and particleboard, textiles, and fuel (Abdul Khalil *et al*., 2010).

Kenaf cultivation and production situation: domestic and foreign countries

In 1960s, Korea recognizes kenaf as the promising non-wood fiber for gunny sack production (Kang *et al*., 2004). After this time, kenaf cultivation has not been done in Korea. Since 2010, kenaf has been used as forage crop. In 2022, about 100 ha of kenaf were cultivated in reclaimed land, Saemangeum in Jeollabuk-do, to be utilized as roughage forage (Fig. 1). Research and development activities in many fields are being continually carried out to create kenaf-based products.

In 1985, the global kenaf production reached an all time high of 2.8 million tons. Since then, kenaf production has shown a declining trend. In 1995, its production was about 0.75 million tons and continued to decline. Almost 0.28 and 0.23 million tons of kenaf were produced in 2010 and 2015, respectively (Table 1) From 1985 to 1995, the sharp drop of kenaf production was attributed mainly to the widespread use of synthetic fibres (Alexopoulou and Monti, 2013; FAO, 2016). However, the decline in kenaf production has been moderate since 2000.

According to FAO (2016) the main cultivation areas for kenaf are the order of India, Bangladesh, China, Nepal, Indonesia, Vietnam, and Thailand in the countries of the Far East.

Industrial attractiveness and environmental benefits of kenaf

Kenaf consists of four important useful components; seeds, stems, leaves, and flowers. Each of these components has different uses. Some of the important industry applications on the kenaf are tabulated in Table 2.

The kenaf leaves which are rich in antioxidants and phenolic contents are used as vegetable (Ryu *et al*., 2017). Its seed has been used as an alternative derivative of edible oil for human consumption (Cheng *et al*., 2016; Mariod *et al*., 2010). The high cellulose content makes kenaf an interesting crop that can replace wood pulp and petroleum-based products (Dempsey, 1975a; Webber *et al*., 2002). On top of that, kenaf biomass can be used as a feedback for many

Table 1. World production of kenaf

Years	1985	1995	2000	2005	2010	2015
Million tons	2.8	0.75	0.51	0.31	0.28	0.23

Fig. 1. Kenaf production for roughage forage in reclaimed land, Saemangeum in Jeollabuk-do, in 2022.

Table 2. Reported industry applications of kenaf in various fields

Categories	Products	Applications
Leaf	Fresh/Extract	Vegetable Bioactive constituent Natural antioxidant
Seed	Edible oil	Medical usages Milk
Stem	Tradition items	Sacking, Hessian Rope, Cordage
	Pulp	Paper, board, textile
	Fibre	Insulation Absorbent Kenaf-glass Building material
	Board	Particle board MDF, Hardboard Cement fibre board Oriented strand board
	Biofuel	Pellet, Syngas, Hydrogen
	Bioplastic	Mulch, Automobile
	Activated carbon	Filter for car, purifier
	Composite	Epoxy, Block Reinforced thermoset

industrial applications because approximately 40% of the kenaf plant stem can be transformed into fibres (Nadzri *et al*., 2020). Its fibers have been utilized to develop alternatives of synthetic products such as plastic, fiber glass, biofuel, activated carbon, and epoxy composite. For example, NEC Corp., Japan, has developed a heat-conductive bioplastic from kenaf fiber in order to increase the recycling rate of its vehicles and mobile phones (NEC Corporation, 2006). Toyota Motor Corporation has used sustainable material obtained from kenaf fiber to produce an electric vehicle, which has joined with Covestro (Covestro, 2020). Israeli company Kenaf Ventures manufactures thermal insulating plaster, masonry blocks, and walls made of kenaf fibers for construction (Kenaf Ventures, 2021). Also, researchers and industries successfully yielded bioethanol, biomethanol, biodiesel, biogas, bio-hydrogen from kenaf, and indicated that it has also potential to use as conventional solid fuel (Kojima *et al*., 2014; Lee *et al*., 2021; Meryemoglu *et al*., 2014; Park *et al*., 2021). Recently, the scope of research using kenaf has been expanded. The Kenaf-based material was developed for supercapacitor, canister, and epoxy (Lee *et al*., 2021; Saeed *et al*., 2020; Silva *et al*., 2021). Furthermore, the fibers, being several times more absorbing than any other known natural product, are used in cleansing oil and chemical spills (Tan *et al*., 2021). And, kenaf can be used as a potential crop to remediate heavy metal-contaminated soil and water (Ding *et al.,* 2016; Santos *et al*., 2010; Shamsudin *et al*., 2016; Uddin *et al*., 2016). The results meet environmental goals and demand from end-users for more sustainable solutions. Hence, kenaf is an effective alternative of non-biodegradables, and can thereby alleviate the levels of environmental pollution. Considering the eco-benefits of kenaf, it is imperative to support and promote it so as to follow the vision of sustainable development. The 'green tag' is further associated with kenaf because it produces the largest biomass among crops and trees, and scavenges extensive amounts of CO_2 and NO_2 from the atmosphere, at a rate 3-5 times faster than forests (Li and Huang, 2013). The plant also inhibits soil erosion by virtue of its deep penetrating roots. Even from the economical point of view, it is essential to promote kenaf. The plant grows quickly to a height of 12-14 feet in less than 6 months (Taylor, 1993). It yields 6-10 tons of dry fiber per acre per year, which is 3-5 times greater than that for trees, which can take even 20 years to reach harvestable size (Dempsey, 1975b). In Korea, the idea of using kenaf as a replacement of synthetics has not yet developed. Scientific and industrial passion in this direction is the prime necessity for innovation and augmentation of the uses of this multi-faceted plant in this country. It is time that we introduce kenaf to be beneficial for agriculture, environment, and industry in the environmental pollution era.

The plant has fascinated much interest and attention in the last decade due to the growing concerns of global warming and the rising price of petro-leum-based products. The advantages of kenaf are high biomass, short life cycle, fast growing, wide growth area, strong adaptability to environment and low cost in cultivation. So, kenaf is regarded as the fiber crop of the twenty-first century. There are several reasons to grow kenaf. In agriculture practice, kenaf needs low quantities of chemical fertilizers during the growth. From the climatic environmental aspect, it absorbs CO_2 at a significantly high rate. Kenaf-based products require less chemicals, heat and time to pulp kenaf fiber because they are not as tough as wood pulp and contain less lignin. Plastics have a problem of not being biodegradable and thus they are environmentally unfriendly in a world where there is increasing interest in use of natural fibers in diverse industrial sectors. Moreover, the potential of replacing synthetic polymers to reduced use of fiberglass, greater recycled paper quality, and timber in industrial products are its additional applications. Therefore, these are used to encourage in highlighting the flourishing and bright future for the persistent extension of kenaf as an agriculturally, environmentally, and industrially profitable crop.

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Conflicts of Interest

The authors declare that they have no conflict of interest.

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