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Gibberellic acid (GA_3) affects growth and development of some selected kenaf (*Hibiscus cannabinus* L.) cultivars

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ABSTRACT

Kenaf (*Hibiscus cannabinus* L.), is a potential alternative of natural wood fibers for biocomposite and pulp and paper industry. However, the average fiber length of kenaf is usually shorter than the critical length to be used for high quality biocomposite materials. Increasing fiber length and quality can diversify its application in fiber based industries. Gibberellic acid (GA_3) is an important plant growth regulator that is actively involved in cell elongation and other important physiological functions in plant growth, development and flowering. To investigate the effects of gibberellin on growth, morphology, and fiber quality, some selected cultivars of kenaf plants were treated with aqueous solution of varying concentrations of GA_3. The effects on vegetative and reproductive growth were evaluated weekly for sixteen consecutive weeks and fiber morphology after harvesting at 18th week. Gibberellin treatment significantly reduced the vegetative growth in terms of stem diameter, leaf number, and leaf size but stimulated fiber elongation, resulted in a tall and slender plant with curled leaves. Gibberellin treatment also impaired reproductive growth by inhibiting floral initiation and development in all treated plants whereas the control plants were in its seed harvesting stage. This study provided novel insights into the effects of GA_3 in regulating vegetative and reproductive growth of kenaf as well as improving its fiber properties.

1. Introduction

Demand for natural fibers is increasingly growing which are mainly obtained from woody plant or trees of natural forest and has been used as a main source for most of the fiber based industries. Along with other fiber based products and biocomposite materials, global consumption of paper is at a high level and continues to grow especially in Asia, where approximately 400 million tonnes of paper and paper based products are produced globally. Asia accounts for the third largest global producers of paper and paper based products mostly due to China's rapidly expanding industry. However natural fibers from woody plant materials are diminishing gradually through extensive tree felling and unmanaged consumption of wood sources from natural forest for fiber extraction.

Kenaf (*Hibiscus cannabinus* L.), is a fast growing, non woody multipurpose annual plant species belongs to Malvaceae family, could be extensively used as an alternative source and possess excellent potential to fulfill demand for pulp and paper industries without depleting the resources from natural forest. Statistic showed that it has been used as the third largest fiber crop after cotton and jute due to its excellent cellulosic fiber component and production of large range fiber based products (Ayadi et al., 2011). It also requires comparatively less energy and chemical input during pulping and paper making process compared with the other comparable wood fibers (Bhardwaj et al., 2005; Villar et al., 2009). The kenaf stem consists of two types of fibers namely outer bast (34–38%) and inner core (62–66%) fiber. Kenaf bark exhibits high quality by having thin and long fibers with average length of 2.6 mm but produce low crop yield compared with the core fibers, however, the latter produces thick and shorter fibers with average length of 0.5–0.6 mm give comparatively low fiber derived values (Kaldor et al., 1990). Kenaf fiber has excellent physical strength properties to be used as a source for pulp and paper making. However, its application in paper and biocomposite industries is limited due to its shorter fiber compared with the other fiber crops.

Studies showed that too high proportion of core fibers can exhibit difficulties in processing and manufacturing industry. Usually larger fibers exhibit excellent mechanical properties with greater strength compared with the shorter fibers for flexural and impact properties.

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Flexural strength considerably increases by 67% using longer fibers whereas decreases significantly with reduced fiber length or using fiber length below the critical length. Thus the end uses of these fibers for manufacturing and production mainly depend on their physical, chemical, and structural properties (Shibata et al., 2006). Since the utilization of these two fibers differs mainly on the quality of the end uses, the enhanced fiber quality as well as the yield of kenaf is a lucrative target of many industries for maximum utilization. However, the use of whole stem together is more preferable in the industries as it gives considerable advantages.

Elongation of kenaf fibers and their quality improvement can be achieved through the manipulation of some of its controlling environmental factors along with the incorporation of plant growth regulators. The use of phytohormones, particularly gibberellic acid (GA_3) is known as an essential growth hormone for controlling various physiological activities such as growth, flowering, ion transport, mediator for acclimatization of plant to leaf canopy, stimulation of leaf area expansion, stimulate elongation and osmoregulation in internodes, dry matter and biomass production, overcome dwarfism, increase germination percentage and seedling growth, and enhancing the sink potential (Brock, 1993; Davie, 1995; Azuma et al., 1997; Kaur et al., 1998; Kaur et al., 2000; Elanchezhian and Srivastava, 2001; Gupta and Datta, 2001; Ouzounidou and Ilias, 2005; Ramesh and Kumar, 2006).

Exogenous application of GA found to be delaying maturation and ripening in a number of fruit tree species. For instance, GA spray on persimmon fruits 2 weeks prior to harvest resulted in delayed ripening of fruits on the tree as well as delayed fruit softening after harvest (Arie et al., 1996). A decrease in the respiratory activity and a delay in anthocyanin synthesis and chlorophyll degradation due to exogenous GA on strawberry fruit have an inhibitory effect on their fruit ripening as well (Martinez et al., 1994). Gibberellin also been used to increase fruit set; reduce fruit abscission and spray of GA (15–30 mg/L) at full bloom stage significantly increased yields by 50–400% (Blumenfeld, 1981).

Manipulation of the GA pathways in some plants species resulted in conspicuous differences in plant phenotype and flowering habit due to alteration in their GA levels. Overexpression of GA 20-oxidase gene in transgenic plants can be explained in two different ways. Higher content of active gibberellins in transgenic plants overexpressing a GA 20-oxidase gene resulted in plants with elongated phenotype but unaltered flowering behavior (Vidal et al., 2001). In contrast, reduction in the level of active gibberellin in transgenic plants overexpressing a GA 20-oxidase gene induced dwarfism but flowered later than the wild type (Ubeda-Tomas et al., 2006). Previous results on cloning and characterization of GA 20-oxidase gene on kenaf showed variation in flowering habit and vegetative growth due to increased gibberellin amount in plant tissues. The transgenic kenaf plants flowered later than the wild type and produced non-flowering type with short to tall phenotype (Withanage et al., 2015). This result agrees with other phenotypes shown by GA2oxs overexpressing transgenic plants such as rice (Sakamoto et al., 2001), *Arabidopsis* (Schomburg et al., 2003) and *Nicotiana sylvestris* (Lee and Zeevaart, 2005). To further investigate the role of gibberellins in plant growth, flowering, and fiber elongation in kenaf, exogenous application of GA_3 under controlled environment were carried out through foliar spray to confirm the phenotype of the existing transgenic lines are induced by endogenous level of GAs or caused by the environment factor. Thus the objective of this study is to evaluate the effects of exogenous foliar application of GA_3 on vegetative and reproductive growth of some selected kenaf cultivars. The research intended to investigate whether the increase in GA content of the kenaf can accelerate the cell elongation and further improve their fiber quality.

Table 1
Description of *Hibiscus cannabinus* cultivars used for application of gibberellic acid (GA_3).

Cultivar	Code	Source	Flowering type
V36	V1	Malaysia	Intermediate
HC 2	V2	Bangladesh	Early
V4202	V3	Bangladesh	Early
HC 95	V4	Bangladesh	Early
Hybrid China	V5	China	Early
Fuhong 952	V6	China	Early

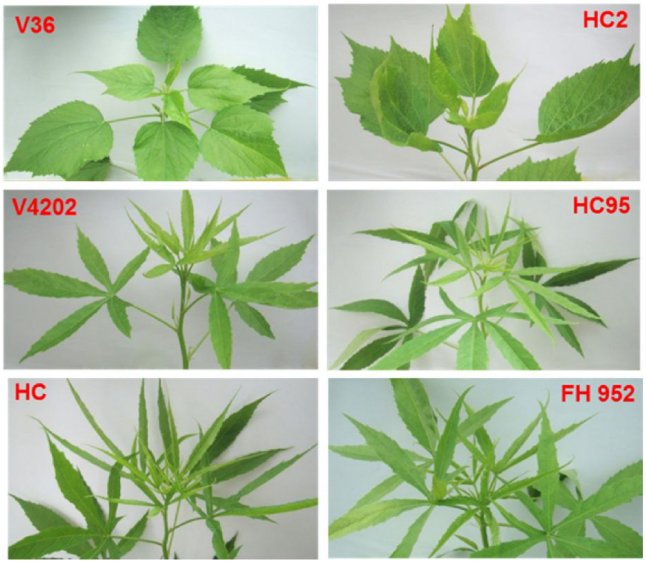

Fig. 1. Shape of leaf for each cultivar grouped into lobed and unlobed.

2. Materials and methods

2.1. Plant materials

Seeds of *Hibiscus cannabinus* cultivars were purchased from China and Bangladesh. Six cultivars were chosen according to their growth, yield, and flowering behavior namely, Fuhong 952 and Hybrid Kenaf (cultivars from China), HC 2, HC 95, and V4202 (cultivars from Bangladesh) and V36, the Malaysia's commercial cultivar (used as control) (Table 1 and Fig. 1). The seeds were fumigated and mixed with fungicide and were kept in 4 °C refrigerator prior to use.

2.2. Seedlings establishment

Healthy seeds of uniform size were surface sterilized with 5% commercial bleach, Clorox (NaOCl) solution for 5 min and soaked in water for 3 h. The pretreated seeds were sown in polystyrene trays/germination trays filled with peat soil for germination. Germination percentage of each cultivar was determined just after the actual germination. The healthy and uniform sized seedlings were then selected individually from the germination trays and transplanted into polythene bag (20 cm × 40 cm) filled with a mixture of top soil, sand, and peat (5:3:1) as potting medium two weeks after sowing. The seedlings were dispatched and transported to the nursery and left in the shade for another one week for further conditioning and hardening-off to new environment. The seedlings were arranged in rows in a net house and irrigated regularly with tap water whenever required. The seedlings were raised in the nursery of the Faculty of Forestry, Universiti Putra Malaysia (2° 59′ N, 101° 42′ E), Serdang, Selangor, Malaysia for a period of 16 weeks from November 2015 till March 2016. The study area experiences typically hot humid climate with temperature ranging