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Research Article
Effects of Irrigation Treatments on Biomass Production of Different Kenaf Varieties

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Abstract

Background and Objective: Kenaf (*Hibiscus cannabinus* L.) is fast growth warm-season crop, traditionally used as a source of raw material for rope, canvas and sacks. Recently, it has been identified as a good source of cellulose pulp for paper industry. Continuously increasing demand of raw material in timber industries and increase in deforestation support adopting Kenaf as an alternative source of non-wood raw material. This study aimed to determine the optimal level of irrigation for maximizing vegetative growth of Kenaf varieties grown in high hydraulic conductivity soils and at the same time ensured the highest water use efficiency. **Methodology:** In this study a controlled irrigation experiment was conducted in UPM research farm to assess response of new exotic varieties HC95, FH952 compared to V36, a well-adapted variety to Malaysian conditions. Deficit irrigation (DI) which is one way of maximizing yields per unit of irrigation water was applied where Kenaf were exposed to a different level of water stresses during the growing season. Physiological attributes, growth performance and total biomass production were measured to investigate the response of these varieties to the different irrigation regimes. **Results:** Results showed among the three (100, 60 and 30%) total water irrigation, there was no significant difference between varieties. Water use was similar among water regimes, whilst irrigation water use efficiency (IWUE) progressively increases with the decrease total volume of water applied by irrigation. **Conclusion:** Water supply was not a limited factor in Kenaf production.

Key words: Kenaf, Water use efficiency (WUE), deficit irrigation (DI)

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Kenaf (*Hibiscus cannabinus* L.) *Malvaceae* is an annual fiber crop of tropical origin indigenous to Africa and is considered to be a potential source of raw material for manufacturing paperboard products and may also be a substitute for fiberglass and other synthetic fibers. As a fibrous crop, Kenaf appears to have enormous potential to become a valuable biomass crop[1]. Kenaf has high potential to be used as a raw material for boards with low density panels, suitable for both sound absorption and thermal resistance[2]. It also has been used as a raw material alternative to wood in pulp production and the paper industries[3] reducing chemical and energy use for paper production and greater recycled paper quality. The inner part of the plant (core) can be used as an adsorbent animal bedding material[4]. Since the plant is fast-growing, up to 4-5 m within 4-5 months and has potential for carbon sequestration[5]. Kenaf has high adaptability to all kinds of soils, also has potential to be planted on soils that have low productivity and were poor in water-holding capacity and nutrient availability[6,7]. In Malaysia, where fertile land is scarce, the use of less fertile soils is beneficial. It can reduce soil erosion due to water and wind. Where depleting supplies of wood resources increased the stakes for alternative fibrous resource is raised, it was reported that Kenaf is able to produce fiber eight times higher at average 17.8 t ha^{-1} compared to tree fiber at only 2.2 t ha^{-1} annually[8].

Little information is available on water requirements for growing Kenaf under irrigated conditions, particularly with regard to increasing their vegetative growth and water use efficiency.

Even though rain fall quantity is not a big problem in Malaysia but its distribution during plant growth cycle make its necessary to have research about Kenaf water needs during growth season and how to optimizing irrigation scheduling through this time. A study[9] conducted in Setiu, Terengganu, showed that Kenaf diameter and height during the dry season showed poor growth performance when water levels in soil was inadequate. Plants need sufficient amount of water to survive and keep their cells in good conditions at the early stage of development in order to produce new tissues and cells.

Sustainable and optimum usage of irrigation water has become a priority and the application of new irrigation concepts to increase the efficiency of available water become important[10,11]. Previously study showed that evapotranspiration rates were highest in the field capacity and decreased with increasing moisture stress. At the wilting point, it was, only about 40% of that in the field capacity. The lower rates of water loss in the drier regimes reflected that plant's physiological mechanism to conserve moisture under stress conditions[12]. This led to the formulation of concepts such as deficit irrigation (DI) a method of high crop water use efficiency (WUE) and still maintain high crop yields when it is properly used. Deficit irrigation is one way of maximizing WUE for higher yields per unit of irrigation water applied[13]. The expectation is that any yield reduction will be economically less significant compared with the benefits obtained from water saving and cost to irrigate more crops. In this method, the crop is exposed to a different level of water stress either during a particular period or throughout the whole growing season[14]. Literature review revealed that there was scarce information on studies of Kenaf growth under irrigation, water use efficiency and optimum irrigation quantities[15].

This study aimed to determine the optimal level of irrigation for maximizing vegetative growth of Kenaf varieties grown in high hydraulic conductivity soils and at the same time ensured the highest water use efficiency. A better knowledge of the irrigation requirements, biomass accumulation and final dry biomass produced may be helpful for a successful introduction of new Kenaf variety into new cropping systems to adopt in future and provide sufficient irrigation schedule to farmers.

MATERIALS AND METHODS

Location of study: A study was conducted under controlled environment house, No. 2(CES 2), Agro-tech Agriculture Complex, University Putra Malaysia, Serdang, (2°58′54″ N, 101°42′51″ E) for a period of 4 months (August-December, 2013). The minimum and maximum temperatures recorded during the study period inside the glasshouse were 23 and 35°C, respectively. The soil used in this experiment was soil mixture 1:2:3 peat, sand and clay, respectively. Glass house relative humidity was between 85-90% and photosynthetic active radiation (PAR) were in the range of 600-700 µmol m^{-2} sec^{-1}.

Treatments and experimental design: In this study, new varieties HC95, FH950, from Bangladesh and China were tested and compared to well adapted variety in Malaysia, V36. Seeds were obtained from the Laboratory of Sustainable Bioresource Management (Biorem), Institute of Tropical Forestry and Forest Products (INTROP). Raised beds with sizes 1×1 m in length and width and 30 cm depth were arranged in complete randomized design (CRD) filled with soil mixture equal to 300 cm^3 soil per each bed. Soil hydraulic conductivity was determined, according to O'Neal method[16] and the soil hydraulic conductivity (>25 cm h^{-1}) was classified as very rapid. Planting density was 660,000 plants ha^{-1}. Two seeds were planted per each hole on distance between rows 30 and 5 cm inter the rows. When seedlings reached trifoliate stage only one healthy seedling per hole was retained. Chemical fertilizers were applied as follows NPK 15:15:15: 120 kg ha^{-1} (Basal), NPK 15:15:15 120 kg ha^{-1} 2nd, Urea 46% 60 kg ha^{-1}. Fertilizer was scaled down to per bed basis equivalent to 6 g urea and 12 g green fertilizer.

The seedlings were subjected to uniform irrigation of 100% soil available water until 30 days after sowing, to ensure uniform seedling performance before starting the water treatments. Water stress treatments were imposed on the plants 1 month after germination when they were more than four-leaf stage. Water treatments were three different percentages of total soil available water:

W1 = 100% as control
W2 = 60%
W3 = 30% of soil available water

Three varieties were used in this study:

V1 = V36
V2 = CH95
V3 = FH950

Measurements on Kenaf growth parameters: Height, diameter in term of above ground biomass were taken and recorded every 4 weeks for a period of 16 weeks. Plant height was measured using a stainless steel ruler and when height reached 1 m height, a pole was used. The height was measured from cotyledon level reached to the base at the terminal bud. The diameter of the plant was measured at 15 cm above the ground using a digital calliper (Model Mitutoyo 200 mm). Two readings were recorded at the stem for diameter and marked using a permanent marker pen. Total dry matter weight and production of dry matter ha^{-1} were calculated.

Growth parameter of different Kenaf parts and physiological parameters were analyzed using analysis of variance (ANOVA), followed by LSD multiple range test to detect the significant difference among the treatments means[17].

RESULTS AND DISCUSSION

Kenaf varieties showed varied growth performance under different soil available water. There was significant different in plants height between varieties and soil available water. Likewise, the interaction between two factors also significantly differs which was the same findings for Kenaf varieties grown in Mediterranean area[14]. They found that amount of water applied strongly affected plant growth (in terms of leaf area index, plant height and biomass) and final total and stem dry yield, which significantly increased with total applied water. The tallest plant was from T9 (FH950) 293.33 cm, while the shortest plants were obtained from T2 (HC95) 203.33 cm (Fig. 1). Plant diameter also showed significantly difference with soil available water having thicker diameter achieved in T8 (Table 1). Plant height shows good linear relationship with plant dry weight (R^2 = 0.76) (Fig. 2). These findings of Kenaf varieties morphological response were also accordance with a study[15] where variety which is classified as extremely late maturity in China environmental conditions can grew taller among other varieties, whereas intermediate maturity variety like V36 was found to give higher above ground biomass under control conditions in Malaysia. Furthermore, variety HC95 gave thicker and shorter stem under stress[16].

Highest total dry matter was from treatments T8 from variety HC95 while the lowest total dry matter was V36 at treatment level 30% (Fig. 3). Variety significantly affects the results including the interaction with soil available water (Table 2). Variety HC95 dry matter yield were the lowest when soil moisture was at 100% while it had the highest dry matter yield when soil moisture at 30% soil water. These varieties,

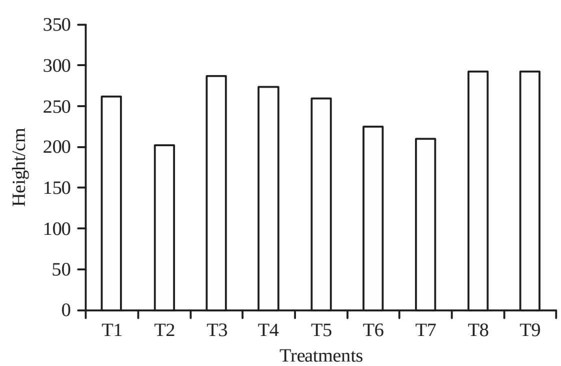

Fig. 1: Water treatments effects on plants height, T1: W1V1, T2: W1V2, T3: W1V3, T4: W2V1, T5: W2V2, T6: W2V3, T7: W3V1, T8: W3V2 and T9: W3V3, W: Soil available water, V: Kenaf varieties

Table 1: Plants height, diameter and total dry matter of different Kenaf varieties under three water treatments

	Soil moisture content (%)		
Varieties	100	60	30
Plants height (cm)			
FH950	288.33±0.92[a]	225.33±0.29[bcd]	293.33±0.27[a]
HC95	203.33±0.18[d]	260.67±0.52[abc]	293.33±0.88[a]
V36	263.00±0.18[abc]	274.33±0.16[ab]	211.00±0.58[cd]
Stem diameter (mm)			
FH950	13.17±0.07[abc]	10.66±0.01[bc]	13.66±0,02[ab]
HC95	9.33±0.10[c]	11.50±0.05[bc]	15.90±0.05[a]
V36	11.50±0.07[bc]	14.66±0.20[ab]	10.66±0.03[bc]
Total dry matter (g/plant)			
FH950	54.60±0.03[abc]	35.97±0.10[c]	78.53±0.02[ab]
HC95	21.93±0.05[c]	39.47±0.05[c]	85.93±0.09[a]
V36	45.27±0.03[bc]	49.73±0.01[abc]	29.53±0.06[c]

Table 2: ANOVA based on complete randomize design (CRD) arrangement for growth parameters

Sources of variation	df	Height	Diameter	DW	DM
MC (%)	2	0.57	0.22	0.04**	0.40
Variety	2	0.36	0.97	0.36	0.07
MC *variety	8	0.0012**	0.02**	0.03**	0.08

Significant difference at $p \leq 0.05$, **The treatments with significant differences, ns: not significant, Where DW: Dry weight and DM: Dry matter

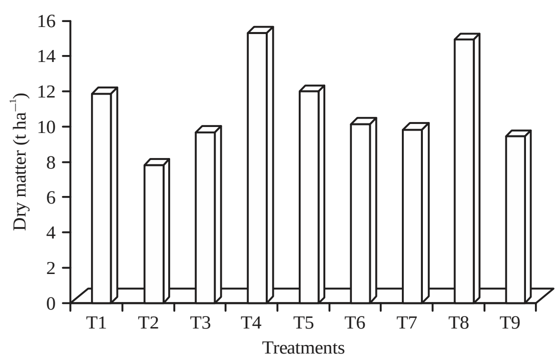

Fig. 2: Irrigation treatments effect on total dry matter production

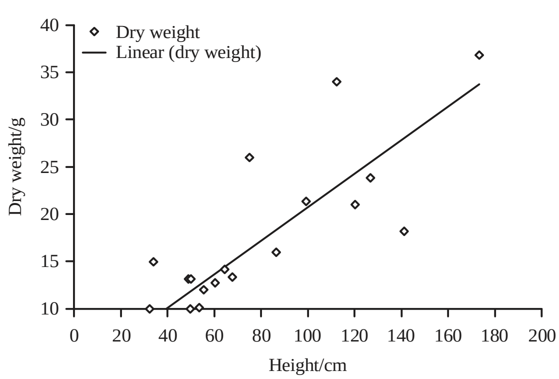

Fig. 3: Relationship between plant height and dry weight

HC95 and FH950 showed higher dry matter yield from low water input (30%) more than doubled compared to the V36 variety. This finding may contradict with the finding in as study[18] in Greece where when Kenaf plants were irrigated well, higher dry matter yields were achieved. This contradiction maybe due different climatic region where this study was conducted and different varieties were used. These varieties grow well even though the moisture was 30% of the soil available water. These species have the potential to be planted in water deficit areas such as the Bris soil in the coastal area of East peninsular Malaysia.

Because of controlled conditions in glass house and very high levels of humidity inside, the plants physiological behaviours were not much different. It may be possible that in open field environment same treatments gave different physiological responses. From above results we can conclude that deficit irrigation (DI) methods encourage high crop water use efficiency (WUE) and can maintain high crop yields if it is properly used[19,20]. Therefore, deficit irrigation (DI) is one way of maximizing WUE for higher yields per unit of irrigation water applied[21]. Applying irrigation to Kenaf in optimum amount could insure the highest production with less irrigation.

CONCLUSION

It is concluded that, the results showed that water supply was not a limited factor in Kenaf production even in dry season if irrigation provided in optimum quantity. More water use efficiency can be obtained and good irrigation scheduling can be provided for farmers depending on readings of soil available water using simple sensor like soil moisture meter. Therefore, if research findings on Kenaf water requirement and varieties behaviours are widely used among farmers, 60% of irrigation cost and water consumption can be saved while producing high total yield reach 25 t ha^{-1}.

SIGNIFICANCE STATEMENT

This study discovers the responses of different varieties of Kenaf to different level of irrigation. Kenaf varieties FH950 and HC95 responded well in low irrigation input. This study will help the farmers in planting Kenaf optimally by using less water input with higher productivity.

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