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Full Length Research Paper

Growth characteristics and biomass production of kenaf

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Kenaf (*Hibiscus cannabinus* L.) is one of the important fibre crops next to cotton, which is planted throughout the world. It is cultivated for its core and bast fibres. Unlike cotton, the fibre of kenaf is obtained from vegetative part of plant. Hence, growth and biomass production of kenaf is a fundamental issue that should be considered for its successful commercial cultivation. This study was designed to elucidate growth and biomass production of three kenaf (*Hibiscus cannabinus* L.) varieties; Guatemala 4 (G4), kohn-kaen 60 (KK60) and V36. 24 plants of each varieties were cultivated in completely randomize design under control conditions throughout a period of 105 days. Parameters of height, diameter and internode were measured within four to six regular intervals of 10 to 15 days, while biomass production parameters of dry one meter stalk mass (DMSM), defoliated plant mass (DPM), one meter stalk mass (MSM) and fresh plant mass (FPM) were measured at harvest time. There was no significant difference between them in terms of diameter and number of internode. However, KK60 was found to have significant higher height than V36 and G4. The varieties, G4 and KK60, showed significant greater fresh plant mass (FPM), defoliated plant mass (DPM), one meter stalk mass (MSM) and dry one meter stalk mass (DMSM) than V36. In all of biomass parameters of FPM, DPM, MSM and DMSM, the highest value belonged to G4 except for DMSM where KK60 showed greater value. Results of this study indicated that G4 is a more efficient variety of kenaf for biomass production compared to the other two varieties of KK60 and V36.

Key words: Kenaf, biomass, growth, internode.

INTRODUCTION

Hibiscus cannabinus L. or kenaf is a short-day, annual, herbaceous plant. It belongs to the family *Malvaceae*, which is important for both its horticultural and economic value (Dempsey, 1975; Webber, 1993). Kenaf is comercially cultivated in more than 20 countries (FAO, 1998). Although, ninety percent of the sown area and more than 95% of total production belongs to China, India and Thailand (FAO, 2003), it is also commercially cultivated in Vietnam, Iran, Russia, Mozambique, Taiwan, El Salvador, Guatemala, Ivory Coast and Nigeria (Dempsy,1975). Kenaf (*H.* cannabinus L.) is a rapidly growing crop of great interest as a source of natural fiber.

It is a valuable biomass crop of the future, which can provide raw material for industrial applications. The traditional uses of kenaf comprising of its use as a source of fibre for making ropes, sacks, canvas, and carpets (Dempsey 1975). Recently, it is used as pulp and papermaking, oil/chemical absorbents (Goforth, 1994) and bioremediation, paperboard products, a substitute for fibreglass, filtration media making, and food and bedding material for animals (Kugler, 1996; Sellers and Reichert 1999).

There are only few references regarding the agronomic aspects of kenaf. However, some literature have studied

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Table1. Means of 100 seeds' weight (g), germination rate (%) and 50% flowering time (day).

Parameter	G4	V36	KK60
Weight of 100 seeds (g)	2.925	2.974	2.431
Germination rate (%)	80	70	60
50% flowering (day)	103	90	68

the adaptability and biomass productivity of few kenaf varieties (Alexopoulou et al., 1999, 2000; Kipriotis et al., 1998; Mambelli and Grandi, 1995; Manzanares et al., 1993; Pertini et al., 1993; Quaranta et al., 1998). Crop productivity and yield are important factors which differ among varieties and even cultivars of plant (Ching et al., 1992; Webber, 1993). Since information regarding productivity and growth characteristics of kenaf are very few and have not been explored in detail, such knowledge of growth and biomass characteristics can hold the better perceptive of kenaf production. Therefore, this study was designated to explain growth pattern of different stages as well as biomass production of three kenaf varieties.

MATERIALS AND METHODS

Site location

A pot experiment was conducted in greenhouse at University Putra Malaysia. The experimental site was latitude N 02°59', longitude E 101°43' and altitude of 64 m above the sea level. The experiments were carried out with mean greenhouse temperatures of approximately 25 and 20°C day and night, respectively.

Plant material and green house experiment

The three kenaf varieties namely Guatemala 4 (G4), V36 and kohn-kaen (KK60) were selected as treatment variables for this experiment. Seeds were obtained from the Laboratory of Sustainable Bioresource Management, Institute of Tropical Forestry and Forest Products, Malaysia. Weights of 100 seeds of each variety were measured, and then sown in trays filled with peat soil on 13th January, 2009. Germination rate for each variety was recorded. The experiment was laid out in complete randomized design. The seedlings were transferred into pots containing soils prepared by mixing sandy, clay, and peat soils in 2:1:1 ratio. Pots with 25 cm diameter, 20 cm height and containing approximately 4 kg of mixed soil were used. Three seedlings were grown in each pot and at trifoliate stage only one healthy seedling per pot was retained. The plant received N, P and K every two week. For insect protection, the insecticide diazinon was used as needed. Pots were watered every other day.

Growth and biomass parameters

According to the SPDG (Sustainable Projects Development Group of the UK) suggestions and literatures (Ahmad et al., 2001; Pace et al., 1998), the following traits were measured in 10 plants from each variety; fresh plant mass (FPM) - the weight of whole fresh plants, defoliated plant mass (DPM) - the weight of whole fresh plants without leaves, plant height (PH) - the height of the whole plant, basal diameter (BD) - the diameter of the base of plant, just above ground, one meter stalk mass (MSM) - the weight of one meter of fresh stalk taken from the middle of the plant, dry one meter stalk mass (DMSM) - the weight of one meter stalk that was put into an oven to dry for 5 days at 60° C and internode

Statistical analysis

Analysis of variance was used to test the difference of varieties for each parameter. Data were subjected to two ways analyses of variance (ANOVA) and PROC GLM was used to test for the significance of these random effects (SAS Institute, 2004). Data of different parameters were analyzed statistically and effects of developmental stage on each parameter were evaluated by analysis of variance (ANOVA) followed by multiple comparison of means, using Duncan's method. Results were expressed as means and differences were assessed as significant at $P < 0.05$.

RESULTS

The results obtained from weight measurement of the 100 seeds showed that V36 had higher weight (2.974 g) than the two other varieties of G4 and KK60 with 2.925 and 2.431 g, respectively. As depicted in Table 1, greatest germination rate (80%) was found in G4, follow by V36 (70%) and KK60 (60%). According to 50% flowering data, it was also clear that G4, V36, KK60 are late, intermediate and early flowering varieties respectively (Table 1).

Regarding growth parameters, at the first measurement (day 24), although, height, diameter and internode of three kenaf varieties did not differ significantly (Table 2), V36 showed the greater value of those parameters than the two others (Figure 1). Interestingly, at second measurement (day 33), this condition change com-pletely and significant lowest value of growth parameters were recorded for V36, while the two other varieties showed almost identical values (Table 3). This change of condition continued for next stage of measurement (day 46), so that although, not significant, but the lowest value of height, diameter and internode was seen for G4, while V36 and KK60 showed almost the identical values (Table 4). At the forth measurement (day 69), this condition continued (the lowest values still belonged to G4), except that KK60 had increased value of three parameters than

Table 2. Means of growth characteristics of three 24 days old *Hibiscus cannabinus* varieties; G4, V36 and KK60. The *F*-statistics for ANOVA models comparing varieties differences in each characteristic are presented.

Characteristic	Variety			ANOVA	
	G4	V36	KK60	F-value	Pr > F
Height	27.1[a]	30.9[a]	26.6[a]	2.189	0.134
Diameter	3.0[a]	3.3[a]	2.8[a]	2.141	0.139
Internode	4.3[a]	5.0[a]	4.8[a]	1.384	0.270

Means followed by the same letters are not significantly different at ($p < 0.05$) according to Duncan's multiple range test.

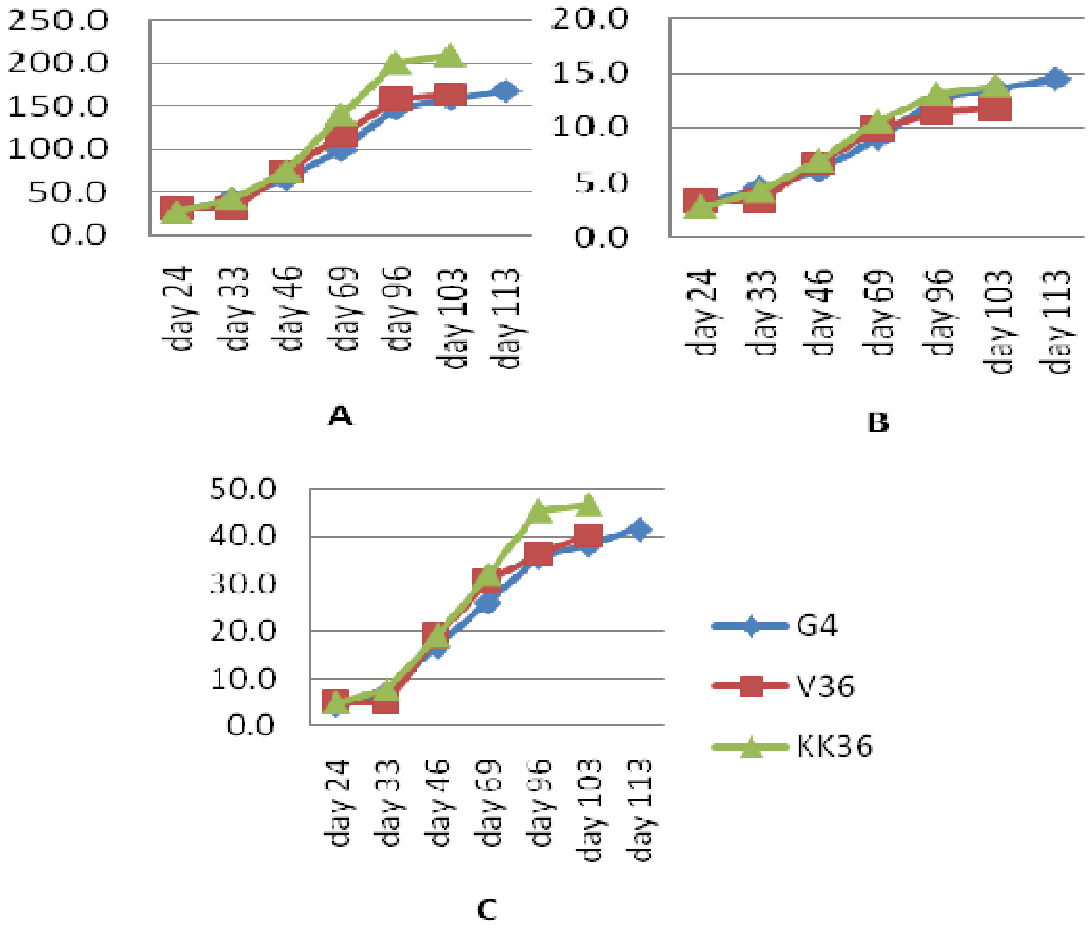

Figure 1. Growth parameters of three *Hibiscus cannabinus* varieties; G4, V36 and KK60. (A) Height (cm), (B) diameter (mm) and C) internode (number) of three *Hibiscus cannabinus* varieties; G4, V36 and KK60, at measurement days of 24, 33, 46, 69, 96, 103 and 113 after their cultivation.

V36 (Figure1). In this stage, number of internode in V36 and KK60 significantly differed than G4. At the same time, KK60 had significant higher height than the two others (Table 5).

Measurement at day 96 and 103 both showed the same result as day 69, except here, KK60 showed significant higher number of internode than both of G4 and V36 (Tables 6 and 7). However, at harvest time, there was no significant difference of diameter and internode between varieties but KK60 showed significantly greater height (209.80 cm) compared with G4(168.56) and V36(163.25) (Table 8). Results of biomass measurement showed that G4 and KK60 were significantly different from V36 (Table 8). In all parameters of FPM,

Table 3. Means of growth characteristics of three 33 days old *H. cannabinus* varieties; G4, V36 and KK60. The *F*-statistics for ANOVA models comparing varieties differences in each characteristic are presented.

Characteristic	Variety			ANOVA	
	G4	V36	KK60	F-value	Pr > F
Height	42.6[a]	30.9[b]	42.7[a]	5.192	0.013
Diameter	4.6[a]	3.3[b]	4.2[a]	6.437	0.006
Internode	7.2[a]	5.0[b]	7.6[a]	12.645	0.000

Means followed by the same letters are not significantly different at ($p < 0.05$) according to Duncan's multiple range test.

Table 4. Means of growth characteristics of 46 days old three *H. cannabinus* varieties; G4, V36 and KK60. The *F*-statistics for ANOVA models comparing varieties differences in each characteristic are presented.

Characteristic	Variety			ANOVA	
	G4	V36	KK60	F value	Pr > F
Height	65.4[a]	74.0[a]	74.8[a]	1.112	0.345
Diameter	6.1[a]	6.8[a]	7.0[a]	2.124	0.142
Internode	16.8[a]	18.9[a]	19.0[a]	2.166	0.137

Means followed by the same letters are not significantly different at ($p < 0.05$) according to Duncan's Multiple Range Test.

Table 5. Means of growth characteristics of 69 days old of three *H. cannabinus* varieties; G4, V36 and KK60. The *F*-statistics for ANOVA models comparing varieties differences in each characteristic are presented.

Characteristic	Variety			ANOVA	
	G4	V36	KK60	F value	Pr > F
Height	99.6[b]	117.1[b]	140.7[a]	11.122	0.000
Diameter	9.1[a]	9.9[a]	10.6[a]	2.353	0.117
Internode	26.1[b]	30.5[a]	32.0[a]	6.575	0.005

Means followed by the same letters are not significantly different at ($p < 0.05$) according to Duncan's Multiple Range Test.

Table 6. Means of growth characteristics of 96 days old of three *H. cannabinus* varieties; G4, V36 and KK60. The *F*-statistics for ANOVA models comparing varieties differences in each characteristic are presented.

Characteristic	Variety			ANOVA	
	G4	V36	KK60	F value	Pr > F
Height	147.8[b]	147.8[b]	200.8[a]	8.391	0.002
Diameter	12.7[a]	11.5[a]	13.1[a]	.821	0.452
Internode	35.8[b]	36.3[b]	45.5[a]	6.223	0.007

Means followed by the same letters are not significantly different at ($p < 0.05$) according to Duncan's Multiple Range Test.

DPM, MSM, DMSSM, the lowest value belonged to V36, while the highest value of all biomass characteristics except for DMSM, belonged to variety G4 (Figure 2).

DISCUSSION

Considering the results of flowering rate, it is clear that KK60 as an early flowering variety needs a shorter time to mature, while V36 as intermediate and G4 as a late flowering variety have longer duration of vegetative stage. These criteria could be considered when elongated vegetative stage is desirable or unlikely shorter time of flowering is needed. Regarding growth parameters, if we categorize the time of measurement to three stages of one (day 24), two (day 69) and three months (day 96) old

Table 7. Means of growth characteristics of 103 days old of three *H. cannabinus* varieties; G4, V36 and KK60. The *F*-statistics for ANOVA models comparing varieties differences in each characteristic are presented.

Characteristic	Variety			ANOVA	
	G4	V36	KK60	F value	Pr > F
Height	159.3[b]	163.3[b]	198.5[a]	7.114	0.004
Diameter	13.6[a]	11.7[a]	13.8[a]	1.116	0.344
Internode	38.3[b]	40.3[b]	46.9[a]	4.489	0.022

Means followed by the same letters are not significantly different at ($p < 0.05$) according to Duncan's Multiple range test.

Table 8. Means of growth and biomass characteristics of three *Hibiscus cannabinus* varieties; G4, V36 and KK60 when they were harvested. The *F*-statistics for ANOVA models comparing varieties differences in each characteristic are presented.

Characteristic	Variety			ANOVA	
	G4	V36	KK60	F- value	Pr > F
FPM	275.56[a]	122.50[b]	236.00[a]	5.83	0.0087
DPM	185.78[a]	89.38[b]	171.10[a]	5.25	0.0128
MSM	116.20[a]	59.00[b]	96.80[a]	5.96	0.0079
DMSM	17.80[a]	9.08[b]	17.94[a]	4.56	0.0209
Heigh	168.56[b]	163.25[b]	209.80[a]	5.47	0.01
Diameter	14.49[a]	11.75[a]	13.83[a]	1.68	0.21
Internode	41.67[a]	40.25[a]	46.90[a]	2.24	0.13

Means followed by the same letters are not significantly different at ($p < 0.05$) according to Duncan's multiple range test. FPM, Fresh plant mass (the weight of whole fresh plants); DPM, defoliated plant mass (the weight of whole fresh plants without leaves); MSM, one meter stalk mass (the weight of one meter of fresh stalk taken from the middle of the plant); DMSM, dry one meter stalk mass (the weight of one meter stalk that was put into an oven to dry for 5 days at 60°C).

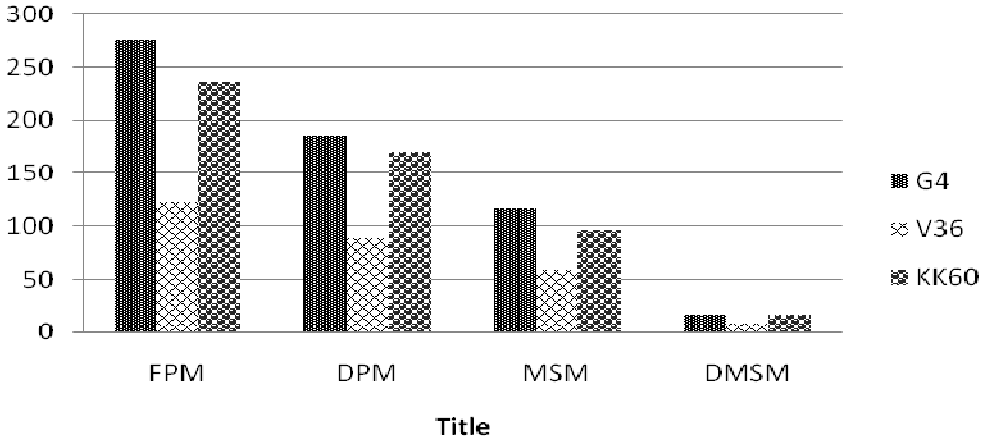

Figure 2. Means (g) of biomass characteristics of three *H. cannabinus* varieties; G4, V36 and KK60. FPM, Fresh plant mass (the weight of whole fresh plants); DPM, defoliated plant mass (the weight of whole fresh plants without leaves); MSM, one meter stalk mass (the weight of one meter of fresh stalk taken from the middle of the plant); DMSM, dry one meter stalk mass (the weight of one meter stalk that was put into an oven to dry for 5 days at 60°C).

plant, except at harvest time, the least number of internode was seen in G4, that is distance of node in stem is highest compared to V36 and KK60. This indicates that this variety has a longer fiber, which is considered as a better quality of fiber. On the other hand, except for first month of growth, in other stages of second and third months, the highest height was seen in KK60.

Meanwhile, biomass assessment showed that G4 and

KK60 both significantly differ from V36 in all parameters. They have greater FPM, DPM, MSM and DMSM than V36. However, G4 was found to have the greatest value of FPM, DPM and MSM, while KK60 had higher value of DMSM than G4. These findings therefore indicate that G4 and V36 are the more economic varieties to grow in terms of biomass production. Finally, this information can be used and continued with more research on further parameters to formulate a clearer variety selection of kenaf to plant.

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