

YIELD AND QUALITY OF TWO KENAF VARIETIES AS AFFECTED BY HARVESTING AGE

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ABSTRACT

Kenaf (*Hibiscus cannabinus* L.) is grown either as an animal feed or as a source of fibre. In Malaysia, the variety V 36 has been planted since 2001 and currently a new variety MHC 123 is being evaluated. This experiment was conducted at the Malaysian Agricultural Research and Development Institute (MARDI) Serdang, (latitude N 3° 17', longitude E 101° 46') from August to December 2012 to determine the optimum harvest age for the two varieties of kenaf for animal feed and for fibre production. The two varieties were harvested at 8, 12, 16 and 20 weeks after planting (WAP). Mean biomass yield of MHC 123 (11.7 t ha⁻¹) was significantly higher (p<0.05) compared to V 36 (8.7 t ha⁻¹). The crude protein (CP) of MHC 123 decreased slowly from 18.06 to 17.22% while CP of V 36 declined rapidly from 21.72 to 11.32% between 8 and 12 WAP. Acid detergent fibre content in MHC 123 increased slowly (31.72 to 36.86%) compared to V 36 (39.57 to 55.59%) from 8 to 12 WAP. From these findings, MHC should be harvested at 12 WAP while V36 should be harvested at 8 WAP for use as forage. Tests on the fibre showed that the tensile strength for both varieties was highest at 16 WAP and both varieties should be harvested at this age for fibre production.

Key words: kenaf, animal feed, fibre, harvest dates

INTRODUCTION

Kenaf (*Hibiscus cannabinus*) has become an important industrial crop in Malaysia as a source of natural fiber for industrial purposes such as for making ropes and sacks and recently as composite building materials. It has been viewed as potential alternative to replace tobacco as a cash crop (Wong *et al.*, 2008). Kenaf was introduced in Malaysia in early 2000 mainly for animal feed. It was usually harvested at an early stage (6-10 weeks) before the start of the reproductive stage. The crude protein (CP) in kenaf is between 21-34% in leaves, 10-12% in stalk and 16-23% in the whole plant (Mat Daham *et al.*, 2006). The CP content of about 20.9% is comparable to white lead tree (*Leucaena leucocephala*) and asystasia (*Asystasia intrusa*). At the young stage of growth (4 weeks), kenaf CP content can reach 28-30% and crude fibre (CF) is less than 20%. However, at 8 weeks cutting, the CP decreased to 16% and CF increased to 36.6% (Wong *et al.*, 2008). Liang *et al.*, (2003) suggested that for the production of high protein feed, suitable age of cutting was between 6-8 weeks. The profile of amino acid of kenaf is similar to alfalfa hay but lower than that of soybean meal. The content of hemicelluloses is about 15%. Tannin content in kenaf is between 1.69-1.97 mg g⁻¹ and these values are lower than those found in oil palm frond or white lead tree (Wan Zahari *et al.*, 2003). Total digestible nutrients (TDN) and metabolisable energy (ME) in kenaf were sufficient to meet daily requirement of ruminant livestock. The average daily weight gain of growing Charoke beef cattle was about 0.66 to 0.71 kg when 30 to 20% kenaf was incorporated in a mixed ration, respectively.

Kenaf has a high growth rate, rising to a height of 4-6 m in about 4-5 months. The dry matter yield averages 6-10 t ha⁻¹ year⁻¹ but new varieties may reach up to 30 t ha⁻¹ year⁻¹. It is similar to jute in many of its properties and may be used either as an alternative, or in admixture with jute. Kenaf has several uses; traditionally, the main interest is its bast fibres, derived from the phloem, but recently the core fibres (xylem and pith) have also been proven useful for industrial application. Bast fibre can be used to make various high quality products such as composite product for building and automotive material. Kenaf fibre is also a replacement for glass fibre and other synthetic fibre. The core fibre can be used directly as a bioremediation agent, animal bedding, low density particle board, soil amendment, oil absorbent in chemical industry and in ethanol manufacture (Sellers *et al.*, 1999; Agbajeet *et al.*, 2008). In the United States kenaf has been planted for paper products (newsprint, bond paper and corrugated liner board) and also for building material (Charles *et al.*, 2002) while in China kenaf is used in the textile industry. Bangladesh, Thailand and Vietnam also produce kenaf but the usage of kenaf is for low value products like rope and sack. In Malaysia, kenaf is grown commercially in many states including Kelantan, Terengganu, Pahang, Kedah and Perlis. From its initial use as an animal feed kenaf is currently grown for its biomass as a primary source for biocomposite products that are regarded as high value building materials.

Harvesting time is an important factor affecting kenaf properties (Zhou *et al.*, 1998). The suitable harvesting age for kenaf depends on the usage and kenaf variety. Various industries harvest the kenaf plants for products at different harvesting times during the plant life cycle. Normally for the purpose of producing fibre kenaf is harvested after the fibre matures (4-5 month after planting or after flower blooming) but for other uses of kenaf especially for forage, kenaf is harvested in 7-8 weeks after planting. This is due to high protein content in the younger plant (Wong *et al.*, 2003). Besides that, fibre from juvenile plants of jute and kenaf was reported to be 'silk-like', fine in texture, very flexible and thin. The yield could be lower but for an annual plant, possibly two crops can be harvested in one season to give the same yield of fibre but with much less lignin. The fibre which can be used for textile may command a higher price resulting from such early harvesting (Roger and James, 1999). For kenaf, lignin occurred in bast fibre at 30 days after planting (Sellers *et al.*, 1999). Immature plant may be low in lignin thus making it more suited for paper manufacture since there would be little chemical pulping required to remove the lignin. The age of kenaf at harvest can influence plant composition and protein content.

Kenaf has a good quality as a source of animal feed and fibre but the limiting factor is the low dry matter yield from the currently grown variety V 36. New varieties have to be introduced and one of the potential variety that is being studied is MHC 123. The growth period for each kenaf variety may be different, so information on harvesting age and yield component on MHC 123 are needed to clarify the ability of MHC 123 to replace V 36. Thus, the objective of this experiment was to determine the optimum harvesting age for MHC 123 and V 36 and to determine the effect of harvesting age on quality and yield of kenaf biomass for forage and fibre.

MATERIALS AND METHODS

The experimental design was a two-factor experiment arranged in a Randomized Complete Block Design (RCBD) with four replications. Treatments comprised of four harvest ages (8, 12, 16 and 20 weeks after planting (WAP)) and two varieties (V 36 and MHC 123). For the production of kenaf as animal feed, the data used were confined to two harvest ages: 8 and 12 WAP as the crop would be too mature as a forage beyond 12 weeks. On the other hand for fibre production the data used were restricted to the 16 and 20 weeks after planting as less mature plants are unsuitable for fibre. Planting material was obtained from Malaysian Agricultural Research Development Institute (MARDI) Serdang. Seeds of two varieties were directly sown into a well prepared site in rows. The row spacing was 35 cm x 5 cm as recommended by MARDI for kenaf V 36. The experiment was conducted at the Malaysian Agricultural Research and Development Institute (MARDI) Serdang, Research Station (latitude N

3°17', longitude E 101° 46'). The soil was ploughed on 1 August 2012 and harrowed a day after. The seeds were sown 2 weeks after ploughing. Planting depth was 2 cm-2.5 cm and sowing was done manually and the plants were thinned to the defined population density at 2 WAP. A basal compound fertilizer, NPK nitrophospka green (15:15:15) was band applied after sowing at the rate of 300 kg ha⁻¹. A subsequent application of 300 kg ha⁻¹ NPK nitrophospka blue special (12:12:17:2 + Te) was applied at 6 WAP. Weeds were manually controlled.

Measurements

Plant height

Plant height was measured with steel ruler from ground level to the highest shoot. The measurements were taken on 10 randomly marked plants from each plot every 2 weeks until harvest.

Stem diameter

Stem diameter was measured 2 cm above the soil using a digital calliper Mitutoyo every 2 weeks until harvest. Measurements were taken on 10 randomly marked plants from each plot.

Dry matter yield

Above ground dry matter yield was measured from four random samples taken from each plot using a 2 m x 1 m quadrat. Samples were harvested manually from each plot and were weighed and dried in the forced-air dryer at 60 °C until constant weight.

Leaf, stem yield and leaf to stem ratio

Kenaf was sampled by using a 0.3 m x 0.3 m quadrat (four replicates for each sampling) at 8 and 12 WAP. The harvested plants were cut at ground level and fresh weight was recorded. Leaves were removed from the stalks and were weighed separately, before and after the samples were oven dried at 50 °C until constant weight. Leaf to stem ratio of the plant is the ratio of the leaf biomass to the stem biomass.

Acid detergent fibre (ADF) and crude protein (CP)

Kenaf was sampled by using a 0.3 m x 0.3 m quadrat (four replicates for each sampling) at 8 and 12 WAP. The plants were harvested at ground level. The plants were oven dried at 50°C until constant weight. Dried samples were ground through 1 mm screen and analysed for CP and ADF content by using Near Infrared Reflectance Spectrophotometer (NIRS) (Brand FOSS, model no. N6500) using prior calibration specifically for kenaf. Acid detergent fibre measures the most indigestible component of the cell wall (mainly cellulose and lignin) and is negatively correlated with digestibility of animal feeds (Van Soest, 1967).

Number of days to flowering

The number of days to flowering was quantified from planting date to the day when the first 50% flower and 100% flower of the marked plants bloomed with white yellowish petals.

Fibre quality

Bast yield, core yield and bast and core ratio

Kenaf was sampled using a 0.3 m x 0.3 m quadrat (four samples for each plot) at 16 and 20 WAP. The bark (containing bastfibre) was peeled from each stalk section manually and both components (bast and core) were oven dried at 60°C until no further weight loss was observed. Weights were recorded before and after the drying process. Bast and core ratio represent the percentage by weight of bast compared with the total stalk weight.

Tensile strength test

A random sample of five plants were harvested from each plot and the bark was peeled manually by hand from each stalk to separate the bast and core. The bast section was soaked in water in a fibre tank until the fibres were separated from each other. The process is called the retting process. The retting process took about 30 days to be completed. The fibres were then oven dried at 60°C until constant weight. These fibres were used for the tensile and water absorption test.

Fibre bundle test was performed using an Instron machine 3366 with a crosshead speed of 5 mm/minute. The kenaf fibre samples were glued at rectangular cardboard with a dimension of 30 mm x 70 mm. The same weights of fibre were used for each sample. In this trial, weight of each sample was 0.0120g. The cardboard contained a circular hole right at the centre with a diameter of 20 mm. A detailed illustration of the sample is illustrated in Figure 1.

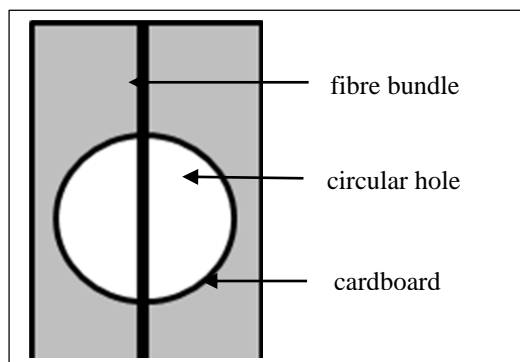


Fig. 1: Mounting card of fibre test piece

Water absorption

Bundles of kenaf fibre were immersed into distilled water which was kept in a covered bottle at room temperature. The moisture content was calculated using Equation 1. A fixed amount of fibre was weighed before and after immersing into water. The weight was taken using an electronic balance after removing the kenaf fibre from the water and wiping them dry. Weighing was done every day until a constant weight was achieved.

$$\text{Moisture (\%)} = \frac{W_t - W_0}{W_0} \times 100 \quad \text{Equation 1}$$

W_t = Weight after immersion

W₀ = Weight before immersion

Data analysis

Analysis of variance (ANOVA) was performed to examine the effect of harvest age and variety on the measured variables tested using SAS® version 9.2. When the effects were significant ($p < 0.05$), means were separated using least significant difference (LSD)

RESULTS AND DISCUSSION

Plant height and stem diameter

Plant height and stem diameter was monitored at 2-weekly intervals. Plant height and stem diameter increased ($P < 0.05$) as maturity advanced for both varieties (Table 1). MHC 123 showed a higher plant height and bigger stem diameter compared with V 36 and this was also reflected in the dry matter yield. The results of plant height and stem diameter from this experiment were considered normal for kenaf planting in the tropical area like Malaysia.

Table 1: Plant height and stem diameter

Treatment	Plant height (cm)	Stem diameter (mm)
Variety		
MHC 123	177.6a	14.36a
V 36	163.0b	12.68b
Week (W)		
W 2	26.2h	2.99h
W4	88.5g	8.33g
W6	141.2f	11.6f
W8	184.2e	14.2e
W10	219.3d	16.4d
W12	243.6c	18.5c
W14	252.8c	19.7bc
W16	270b	20.29b
W18	278b	22.57a
W 20	296a	23.1a
Significance level		
V	**	**
W	**	**
V x W	**	ns
Mean	170.3	13.5
CV	11.16	15.87

Means with the same letter were not significantly different ($P > 0.05$) using LSD.

Above ground biomass

The dry matter yield of kenaf is shown in Table 2. There were significant differences in dry matter yield (DMY) of kenaf between varieties and harvesting age. There was no interaction between harvesting age and variety, thus the discussion is focused on the main effects of varieties and harvesting age. The results showed that the DMY increased significantly ($P < 0.05$) from 1.71 kg plot⁻¹ at 8 weeks to 2.24 kg plot⁻¹ at 12 weeks. However no significant increase in dry matter yield was shown thereafter

at 16 and 20 weeks. Based on these values the extrapolated yield were 8.5, 11.2, 10.9 and 10.2 t ha⁻¹ at 8, 12, 16 and 20 weeks, respectively. The earliest harvest age at 8 weeks gave the lowest biomass because the plants were still actively growing. A similar finding was reported by Charles (1992) who found lower dry matter yield at 8 WAP (4.7 t ha⁻¹) compared with 12 WAP (7.5 t ha⁻¹) for varieties Everglades 41, Cuba 2032, Guatemala 4, Guatemala 45, Guatemala 48 and Guatemala 5. Similarly, Aminah *et al.* (2006) reported that dry matter yield of kenaf variety HC 13, Thai Kenaf, Tainung V 28, Tainung 2, Khonkaen 60 at 8 WAP ranged between 1 to 6 t ha⁻¹. Dry matter yield for forage in our study was considered high when compared to other varieties while for fibre it was similar with finding from Noor Syahira (2010) where dry matter yield for MHC 123 was 11 t ha⁻¹ at 16 WAP.

Table 2: Dry matter yield based on harvest age and variety

Treatment	Dry matter (kg plot ⁻¹)	Yield (t ha ⁻¹)
Harvest age (H)		
8 WAP	1.71b	8.5b
12 WAP	2.24a	11.2a
16 WAP	2.18a	10.9a
20 WAP	2.03a	10.2a
Variety (V)		
MHC 123	2.34a	11.7a
V 36	1.74b	8.7b
Significance level		
Harvest age	**	**
Variety	**	**
H x V	ns	ns
Mean	2.43	12.15
CV	13.66	13.66

Means with the same letter were not significantly different among harvest age and variety ($p > 0.05$) using LSD** $p < 0.01$, ns: not significant.

Dry matter yield of MHC 123 at 11.7 t ha⁻¹ was significantly higher than V 36 (8.7 t ha⁻¹). In Malaysia, DMY at maturity stage (16-20 WAP) ranged from 10-15 t ha⁻¹ (Nik Ablah, 2012). In well established BRIS fertile soil, yield can reach up to 20 t ha⁻¹ at maturity stage.

Number of days to flowering

MHC 123 was later flowering than V 36 (Table 3) which started flowering after 51 DAP and achieved 50 % flowering at 78 DAP followed by 100 % flowering at 103 DAP. V36 started to flower 10 days earlier than MHC 123 (41 DAP) and 50 % of total flowering at 67 DAP followed by 100 % flowering at 88 DAP. For kenaf, the crop is considered mature when 50% of flowers have bloomed. At maturity stage the kenaf growth rate started to slow down and the fibre becomes harder. Noor Syahira (2010) explained that the period of flowering determines the growth of kenaf. Full bloom at 0-30 DAP is considered as very early, 31-60 DAP as early, 61-90 DAP as intermediate and 91-120 DAP as late flowering variety. Thus, MHC 123 was classified as late flowering while V 36 was intermediate. Lateness in flowering gave an advantage to the MHC 123 by extending the period of accumulating biomass as kenaf growth rate was higher at the vegetative phase than the reproductive phase. Lateness in flowering was one of the reasons MHC 123 was greater in DMY compared to V 36. This finding concurred with Noor Syahira (2010) who reported that MHC 123 was later in flowering compared with V 36 at every flowering stage with 57.7, 78.8 and 101.5 DAP for MHC 123 at first flowering, 50%

flowering and 100% flowering respectively and 45, 65.2 and 92.7 DAP for V 36 at first flowering, 50% flowering and 100% flowering respectively.

Table 3: Mean number of days to flowering

Treatment	First flowering	50% flowering	100% flowering
Variety (V)			
MHC 123	51.8a	78.8a	103.3a
V 36	41.5b	67.5b	88.8b

Means within each column with different letters were significantly different at $P < 0.01$ using LSD

Forage quality

Crude protein content

Harvest age showed significant effect ($P < 0.01$) on crude protein (CP) content but no significant difference was shown between varieties. There was significant interaction ($P < 0.05$) between harvest age and variety on CP as shown in Table 4. Thus, the result will focus on interaction between harvest age and variety. The crude protein content from 8 WAP (18.05 %) to 12WAP (17.22 %) in MHC 123 decreased slowly but in V 36 (21.72 to 11.31 % of CP) showed a rapid decline from 8 to 12 WAP (Figure 2). The decrease in CP content at 12 WAP was mainly due to increase in plant maturity and rapid accumulation of fibrous component (Anutet *et al.*, 2009). The CP content in the study by Wan Zahari (2004) was similar with the current work which showed that at 8 WAP the CP content was 21% for V 36. Philips *et al.*, (2002) recorded lower CP (15%) as compared to the MHC 123 and V 36. This shows that the CP content varies between varieties. Even with a lower value of CP content at 12 WAP compared to 8 WAP for MHC 123 the value of 17% CP is acceptable even for dairy cattle (Nocek, 1987). The CP content for MHC 123 was similar with the finding of Abdullah *et al.*, (2006) where CP content ranged between 18 to 15%.

Table 4: Mean crude protein content

Treatment	CP (%)
Harvest age (H)	
8 WAP	20.3a
12 WAP	14.3b
Variety (V)	
MHC 123	18.1a
V 36	16.5a
Significance level	
Harvest age	**
Variety	ns
H x V	**
Mean	17.29
CV	9.62

Means with the same letter were not significantly different among harvest age and variety $p > 0.05$ using LSD.

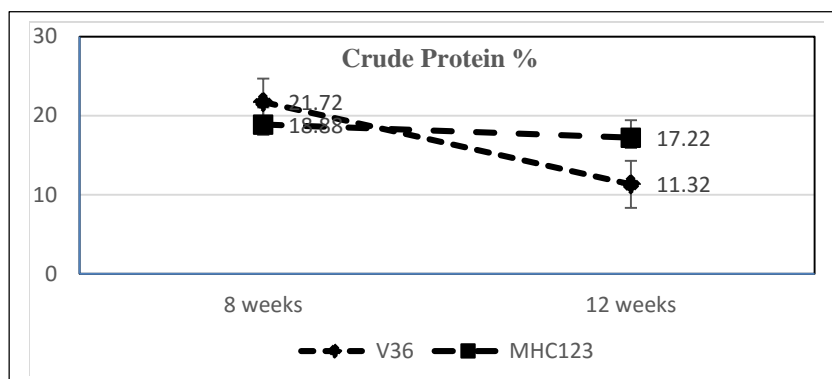


Fig. 2. Crude protein content of two varieties of kenaf harvested at 8 and 12 weeks. (Bars denote standard deviation $n=4$)

Acid detergent fibre content

Acid detergent fibre (ADF) content was significantly affected by harvest age and variety (Table 5). There was also significant interaction between harvest age and variety (Figure 3). Thus the result will focus on interaction between harvest age and variety. At both harvest age, V 36 showed significantly higher ($P<0.05$) ADF content compared with MHC 123. ADF content in MHC 123 increased slowly from 8 to 12 WAP (31.72 to 36.86 %) but in V 36 it increased at a much faster rate (39.57 to 55.59 %). For kenaf, after 50% flowering, the growth rate slowed down and the young stalk became fibrous. MHC 123 was late in flowering compared with V 36. MHC 123 takes about 11 WAP to 50% flowering while V 36 takes about 9 WAP to 50% flowering. ADF content in MHC 123 increased slowly from 8 to 12 WAP because in that period MHC 123 was still actively growing and the fibre in the stalk was still immature. In contrast, the ADF content in V 36 increased rapidly from 8 to 12 WAP because V 36 reached the 50% flowering very early at 9 WAP and the stalk has reached full maturity.

Table 5: Mean acid detergent fibre content

Treatment	ADF (%)
Harvest age (H)	
8 WAP	35.6b
12 WAP	46.2a
Variety (V)	
MHC 123	34.3b
V 36	47.6a
Significance level	
Harvest age	**
Variety	**
H x V	**
Mean	40.93
CV	7.61

Means followed by the different letters were significantly different among harvest age and variety using the LSD ($P<0.05$) ** $P<0.01$.

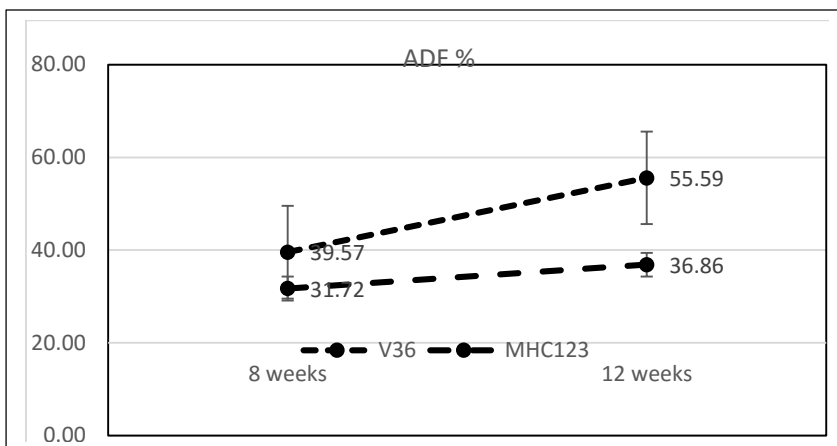


Fig. 3. Interaction between harvest age and variety on acid detergent fiber content. (Bars denote standard deviation $n=4$)

Correlation coefficients between crude protein and acid detergent fiber content

In order to determine the relationship between crude protein and acid detergent fiber content, the correlation between crude protein and acid detergent fiber content were analyzed. There was a significant negative correlation ($r=-0.776$ $P<0.01$) between crude protein and acid detergent fiber content

Leaf yield, stem yield and leaf to stem ratio

Table 6 shows the leaf yield, stem yield and leaf to stem ratio of kenaf. Both leaf and stem yield were significantly higher ($P<0.01$) at 12 weeks harvest compared to 8 weeks. However leaf to stem ratio between the two harvest dates was not significantly different. Generally as maturity advanced, leaves at lower plant part senesced and yield of the stems compared to leaves increased (Anutet *et al.*, 2009). This could be the reason stem yield at 12WAP was higher compared with 8 WAP. Leaf yield of MHC 123 and V 36 ranged from 1.6 to 1.7 $t\ ha^{-1}$ while stem yield of MHC 123 and V 36 ranged from 8.0 to 9.9 $t\ ha^{-1}$. There were no significant difference in leaf and stem yield between the two varieties, however leaf to stem ratio of MHC 123 (0.37) was significantly higher ($P<0.05$) than V 36 (0.16).

Table 6. Mean leaf yield, stem yield and leaf to stem ratio.

Treatment	Leaf ($t\ ha^{-1}$)	Stem ($t\ ha^{-1}$)	Leaf to stem ratio
Harvest age (H)			
8 WAP	1.3b	6.4b	0.20a
12 WAP	2.0a	11.5a	0.17a
Variety (V)			
MHC 123	1.6a	8.0a	0.37a
V 36	1.7a	9.9a	0.16b
Significance level			
Harvest age	**	**	ns
Variety	ns	ns	*
H x V	ns	ns	ns
CV	29.6	18.38	23.23

Leaf yield, stem yield and leaf to stem followed by the same letter are not significantly different among harvest age and variety using LSD ($P>0.05$). ns: not significant * $P<0.05$ ** $P<0.01$

Fiber quality

Bast yield, core yield and bast to core ratio

The components of kenaf as a fibre material include the bast and core fibre. Table 7 shows the yield of bast and core fibre at two harvest ages of the two tested varieties. There were significant differences in bast yield and core yield between the two harvest ages. Harvesting at 20 WAP gave a significantly higher ($P<0.01$) bast yield (3.5 t ha^{-1}) compared with harvesting at 16 WAP (3.2 t ha^{-1}). Similarly, core yield was also significantly higher ($P<0.01$) at harvest age of 20 WAP (5.4 t ha^{-1}) compared with harvest age of 16 WAP (5.0 t ha^{-1}). Bast to core ratios at 16 and 20 WAP (0.65-0.66) were not significantly different between varieties and between harvest age. MHC 123 was significantly ($P<0.05$) higher in bast yield which was 3.4 t ha^{-1} compared to V36 with 3.3 t ha^{-1} . There were no varietal differences in core yield which were 5.1 and 5.2 t ha^{-1} for V36 and MHC 123 respectively. In addition, there was a significant positive correlation ($r=0.767$ $P<0.01$) between bast and core yield, indicating that when bast yield increased, core yield also increased.

Table 7. Mean bast yield, core yield and bast to core ratio of two varieties of kenaf at 16 and 20 weeks.

Treatment	Bast yield (t ha^{-1})	Core (t ha^{-1})	Bast to core ratio
Harvest age (H)			
16 WAP	3.2b	5.0b	0.66a
20 WAP	3.5a	5.4a	0.65a
Variety (V)			
MHC 123	3.4a	5.2a	0.66a
V 36	3.3a	5.1a	0.65a
Significance level			
Harvest age	**	**	ns
Variety	*	ns	ns
H x V	ns	ns	ns
Mean	3.35	5.16	0.65
CV	8.65	11.99	9.37

Bast yield, core yield and bast to core ratio followed by the same letter are not significantly different among harvest age and variety, ** $P<0.01$, * $P<0.05$. ns : not significant.

Tensile test

There was significant interaction between varieties and harvest age on maximum tensile strength ($P<0.01$) (Table 8). Thus, the result will focus on the interaction between harvest age and variety. Figure 4 shows that the tensile strength of MHC 123 was significantly higher compared with V 36 at both harvest age, 16 and 20 WAP. MHC 123 showed a rapid decline in tensile strength from 16 WAP (149.8 MPa) to 20 WAP (53.6 MPa). V 36 also showed a decline in tensile strength but not as drastically as MHC 123 (80 to 39.6 MPa). From the result it could be concluded that maximum tensile strength was at 16 WAP for both varieties but there was a greater decline in tensile strength with later harvest in MHC 123 than V36. Norlin *et al.* (2011) also reported a similar result where maximum tensile strength was found at harvest age of 16 WAP with 118.30 MPa for kenaf fibre. Therefore based on this report the suitable harvesting age for producing fibre for MHC 123 and V36 was at 16 WAP.

Table 8. Maximum tensile strength of two kenaf varieties at 16 and 20 weeks harvest.

Treatment	Maximum tensile strength (MPa)
Harvest age (H)	
16 WAP	114.9a
20 WAP	46.6b
Variety (V)	
MHC 123	101.7a
V 36	59.8b
Significance level	
Harvest age	**
Variety	**
H x V	**
Mean	80.67
CV	16.09

Means with same letter are significant different, ** P<0.001.

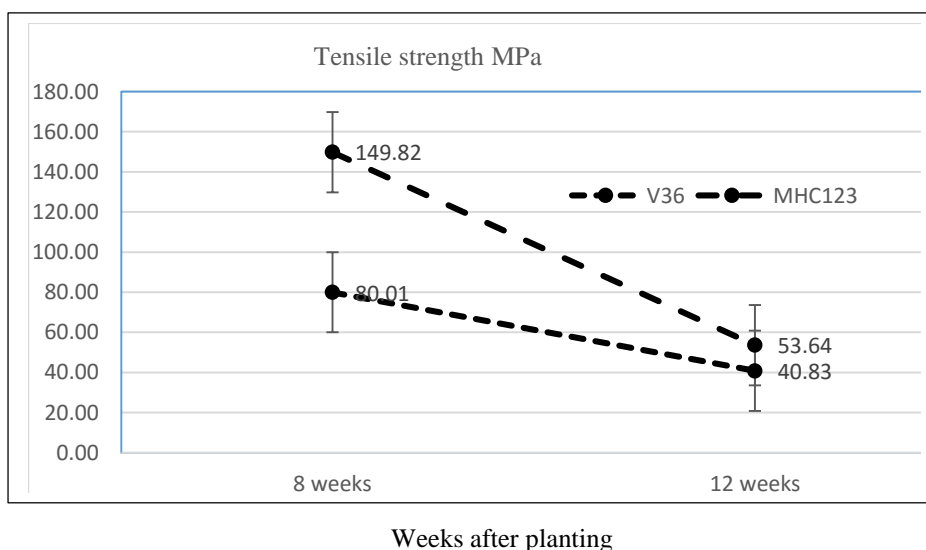


Fig. 4. Interaction between variety and harvest age on tensile strength. (Bars denote standard deviation, n=4)

Water absorption

Significant differences in water absorption was observed among day after immersion (DAI), harvest age (H) and variety (V) as shown in Table 9. However, there was no significant interaction between the factors on water absorption of the fibre. Thus, the result will focus on the main effects on water absorption. From day 1 to day 4 there was slow absorption while from day 4 to day 6 there was a rapid increase in water absorption which became stable from day 6 to day 8. Kenaf fibre has a hydrophilic characteristic, the penetration of water to the fibre makes the fibre swell until a maximum water absorption is achieved. In this study, the maximum water absorption started at 6 DAI.

Fibres from plants harvested at 20 WAP (122.9%) had significantly higher ($P < 0.05$) water absorption compared to those harvested at 16 WAP (117.4%). V 36 had a significantly higher water absorption compared to MHC 123 with 124.3 and 116 % respectively. The desirable quality of kenaf fibre is one with lower water absorption. Therefore, the best quality of fibre was obtained from MHC 123 harvested at 16 WAP. For V 36, a better quality fibre was also found at harvest age of 16 WAP. The higher quality of fibre at 16 WAP was possibly due to the higher maximum tensile strength as compared with the fibre harvested at 20 WAP. From the observation, the fibre from harvest at 20 WAP was easy to break by hand and this could be the reason for the higher water penetration, because once the micro-cracking occurs the hydrophilic characteristic of the fibre will contribute to more water penetrating, creating swelling stress and lowering the fibre strength (Norlin *et al.* 2011).

Table 9: Mean water absorption

Treatment	Water Absorption (%)
1	69.5e
2	77.7e
3	87d
4	99.7c
5	133.6b
6	160.7a
7	166.3a
8	166.6a
Harvest age (H)	
16 WAP	117.4b
20 WAP	122.9a
Variety	
MHC 123	116.0b
V 36	124.3a
Significance level	
Harvest age	*
Variety	**
Day after immersion	**
H x V	ns
H x DAI	ns
DAI x V	ns
H x V x DAI	Ns
Mean	120.3
CV	10.80

Means within day after immersion, harvest age and variety followed by the same letter are not significantly different using the LSD, ** $P < 0.01$, * $P < 0.05$. ns : not significant.

CONCLUSION

The results of this study indicate that varietal differences occur in kenaf and the harvest management should be based on these varietal differences. The new variety MHC 123 showed better yield and forage quality than the current variety V 36. For the purpose of animal feed MHC 123 can be harvested at 12 weeks after planting while V 36 should be harvested earlier. For fibre production both varieties should be harvested at 16 weeks after planting as delayed harvest will cause a reduction in fibre quality in terms of tensile strength and water absorption.

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