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Evaluation of Nutritive Value of Seven Kenaf (*Hibiscus cannabinus* L.) Varieties Harvested Depending on Stubble Height

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ABSTRACT

Protein feed shortage is one of the most important factors that limit the development of animal husbandry in China. Kenaf (*Hibiscus cannabinus* L.) can be used as a high-quality protein feed for livestock. The aims of this study were to evaluate the yield and quality characters of seven kenaf varieties harvested on the basis of stubble height and to screen the varieties with high nutritive value. A reasonable stubble height was selected, and then kenaf varieties were cut leaving the selected stubble height and their nutritive value was determined. The results showed that stubble height of 90 cm was the most appropriate for improving the biomass content and nutritive value of kenaf. The dry matter yield of the whole plants, crude protein content and crude fibre content of the seven kenaf varieties ranged from 15,359.31 kg/ha to 18,502.18 kg/ha, 8.99% to 16.23% and 16.71% to 37.43%, respectively. The nutritive value of the seven kenaf varieties was the same for the first two harvests, but was slightly different for the third harvest due to the cold climate during this harvest time. Variety SZHP35 had the highest nutritive value, dry matter yield (18,502.18 kg/ha) and crude protein yield content (2,027 kg/ha), while variety 4A-4B had higher leaf proportion and yield and significantly higher crude protein content ($P<0.05$) than that of other varieties. Correspondence analysis suggested that 4A-4B was closely related to leaf yield and crude protein content, while SZHP35 was closely related to high yield. Our findings suggested that4A-4B and SZHP35 could be used as forage material in China. .

Keywords: correspondence analysis, kenaf, nutritive value, stubble height

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INTRODUCTION

Protein feed shortage is one of the most important factors that limit the development of animal husbandry in China, especially in south China. The high-quality forage crops grown in the northern region of China such as alfalfa cannot be planted in south China because of the hot and humid climate in summer.

Kenaf (*Hibiscus cannabinus* L.), an annual herbaceous bast fibre crop, has an ability to adapt to varying climate and environmental conditions; it is an important raw material for the traditional textile industry and has been described as a multi-use crop because of its extensive industrial applications (Falasca et al., 2014; Killinger, 1969). It can even grow in saline-alkali soil (Bai et al., 2015; Reta-Sánchez et al., 2010). Many studies have shown that kenaf has a high nutritional value: the crude protein content of the whole plant ranges from 6% to 23% and that of the leaf ranges from 14% to 34% (Swingle et al., 1978; Webber, 1993; Weber, 1993). The tender stem and leaves of the kenaf have good palatability and can be used as feed for livestock and poultry (Ning-Fang, 2006; Rajashekher et al., 1993). Unlike alfalfa, kenaf can be fed to lambs (Phillips et al., 2002); Further, the existing cultivated varieties have high resistance to anthracnose and root knot nematode disease in China, and no pesticides and herbicides are used in the growth period of kenaf. Thus, chemical pollution is very low; hence, studies on kenaf as forage have obvious ecological and economic benefits. Because of the high yield, easy defoliation and reduced branching, the stalks of kenaf are considered more favourable than its leaves, which have lower yield and percentage. However, leaves are very important with regards to the nutritive value of forage, and selection of mature harvest and specific cultivar is important to obtain a high protein and dry matter yield (Chantiratikul et al., 2009; Kipriotis et al., 2015). The harvest date and materials can influence the crude protein content, and the leaf yield and crude protein yield are significantly different across different varieties of kenaf (Webber, 1993; Weber, 1993). Chantiratikul et al. (2009) evaluated the potential yield and chemical composition of kenaf and determined a suitable harvest time. Reta-Sánchez et al. (2010) preliminarily determined the suitable planting density for kenaf as forage. JiYeon et al. (2012) compared the nutritive value of different kenaf cultivars and successfully identified a potential forage cultivar. In Malaysia, Saba et al. (2015) conducted a systematic research on harvest and post-processing of kenaf as forage based on the local ecological and economic conditions. However, studies on kenaf have mainly focussed on the effect of plant maturity or different harvest intervals on its use as forage (Chantiratikul et al., 2009; Danalatos & Archontoulis, 2010; Gonzàlez-Valenzuela et al., 2008; Phillips, 1999; Webber & Bledsoe, 2002; Xiccato et al., 1998), fertilisation measures, field management techniques and cultivation methods (Anfinrud et al., 2013; Bañuelos et al., 2002; Danalatos & Archontoulis, 2010; Reta-Sánchez et al., 2010). However, studies involving multiple harvests of kenaf over the period of one year similar to most studies on forage grass are rare. In this study, kenaf varieties were harvested three times in one growing season.

Kenaf, a tropical crop with high regeneration ability, was thought to adapt very well to the hot and humid climate of south China and it was believed it could be used as a non-grain-based protein-rich feed resource for livestock. It was seen to be a resource for alleviating the food crisis in south China. In this study, kenaf was harvested at different stubble heights, and kenaf varieties with high nutritive value at the appropriate stubble height selected were identified.

MATERIALS AND METHODS

The test material was planted at the Innovation Experiment Base (112°42′E, 28°12′N) of the Institute of Bast Fiber Crops, Chinese Academy of Agricultural Science. The sowing time was 16 May to 20 October for both years of the two-year study. The soil used was clay and it had a pH of 5.1. The following seven representative materials were selected from the existing varieties: Fuhong992, SZHP35-44, H1301, SZHP35, 14-514, 4A-4B and 991FN3; they are marked A, B, C, D, E, F and G in Tables 3 and 4 and Figures 4 to 7.

In the first part of the study, Fuhong992 was used for the trial and planted in a plot (25 m × 35 m) with a row space of 35 cm and planting density of 18,000 plants/ha; one stubble height was selected from three stubble heights (60, 90 and 120 cm). The first harvest was on the 65th day after planting; the second harvest, on the 45th day after the first harvest; and the third harvest, on the 45th day after the second harvest (Figure 1). The crops were harvested three times in a growing season of 155 days. The sowing times and harvest mode of the second part of the study were the same as those in the first part; the stubble height was selected in the first part. Each material was planted in a plot (2.5 m × 35 m) with a row space of 35 cm and planting density of 18,000 plants/ha. In the two parts of the study, about 600 kg/ha compound fertiliser (N:P:K=15:15:15) as base fertiliser was applied at sowing and 225 kg/ha compound fertiliser (N:P:K=15:15:15) as top application of fertiliser was applied after each harvest, and the land was irrigated with sufficient water after fertilisation.

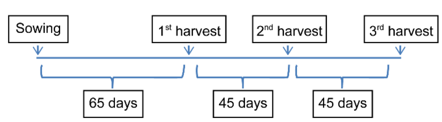

Figure 1. The harvest mode

YIELD DETERMINATION

In our field investigation, the survival rate was above 99%. The kenaf varieties were cut leaving the selected stubble height, and the fresh yield was determined. An area of 4 m2 (2 m × 2 m) was selected randomly from the plot and samples were collected from this plot; the kenaf plants were separated into stems and leaves, and the dry matter (DM) weight of each part was calculated after de-enzyming (dried at 65°C to constant weight after drying at 105°C for 30 min). The DM yield of leaves, stems and whole plants per plot was estimated from the DM of each plant part.

Nutritive Component Determination

The plants sampled to determine the DM yield were also used to analyse the main nutritive components, including crude protein (CP; AOAC 1995), ether extract (EE; ISO 6492:1999), crude fibre (CF; ISO 6865: 2000), ash (AOAC 1995), calcium (Ca; AOAC 1995) and total phosphorus (TP; AOAC 1995).

CP Yield Determination

CP yield of each harvest was the product of the CP content and DM yield; the CP yield of the whole growth period was the sum of the CP yield of the three harvests. The values were converted to a unified measuring unit, kg/ha.

All data were analysed using the SAS 9.2 statistical software. The nutritive components and DM yield, which were classified according to harvest time, were analysed using Duncan's multiple range test. Statistical significance was set at the 5% level. The correspondence analysis for nine traits and seven varieties of kenaf as the subject was analysed using the SAS 9.2 statistical software. The average linkage clustering based on yield and nutritive traits was also analysed using SAS 9.2.

RESULTS AND DISCUSSION

Selection of Stubble Height

First, an appropriate stubble height was selected. Previous studies have shown that the nutritive value of kenaf varies depending on the numbers of days after planting, and the highest nutritive value was obtained at 8-12 weeks (about 55-80 days) after planting (Chantiratikul et al., 2009; Phillips, 1999); however, these studies were based on a yearly harvest. One study suggested that kenaf can be harvested when the stubble height is 12 cm and plant height is 90 cm; the researchers showed that when the harvest interval was 40 days, kenaf could be harvested three times in one growing season, whereas when the harvest interval was 60 days, kenaf could be harvested only twice in one growing season. Nonetheless, this study did not provide information for the optimum stubble height for kenaf (Gonzàlez-Valenzuela et al., 2008). Stubble height has a significant effect on the yield and quality of forage grass (Jinghui et al., 2005; Zhaorong et al., 2013). In our study, almost no leaves remained on the stem below 60 cm after the kenaf was grown for two months after planting; at our study site, the kenaf could be harvested three times in a growing season. On the basis of the findings of previous studies and our observation, three stubble heights (60, 90 and 120 cm) were selected for preliminary analysis, and the harvest intervals were 65, 110 and 155 days, respectively.

Yield Traits of Different Stubble Heights

Table 1 shows the DM yield of kenaf at different stubble heights. The yield of each part and that of the whole plant of the 90-cm and 120-cm stubble height trial groups was significantly higher during the second harvest than during the other two harvest times. The yield of the 60-cm stubble height trial group successively and significantly decreased during the three harvest times (Figures 2a, 2b, 2c). The yields of each part of the three trial groups were the lowest during the third harvest, owing to the cold climate that retarded the growth of the plants. Because fewer leaves remained on the stem after each harvest, the regeneration of the stubble height of the 60-cm trial group was restricted, in particular during the third harvest when the climate was cold.

Plant yield is an important index to evaluate the regeneration ability of plants (Jin-Hong et al. 2011). During the three harvest times, the yield of stems and leaves of the different treatments during the same harvest time were significantly different, indicating that stubble height affected the regeneration capacity and yield of plants, which was consistent with the findings of previous studies (Wang, 2012; Wang et al., 2005). The DM yield of the three trial groups (12,529.16, 15,943.89 and 12,232 kg/ha) during the trial phase (Table 1) was higher than that reported previously (Chantiratikul et al., 2009; Hui-Juan et al., 2012; Reta-Sánchez et al., 2010). This suggests that the DM yield of kenaf is higher when it is harvested more than once a year.

Leaf output is an important factor in evaluating the nutritive value of forage crops: the higher the percentage of leaves, the higher the nutritional value (Webber, 1993; Jinghui et al., 2005; Zhaorong et al., 2013; Zhiguo, 2009). The proportion of leaves, especially that of the stubble height of the 60-cm group (44.8%), was higher than that reported previously (Reta-Sánchez et al., 2010). Since the yield of the whole plants was high, the leaf yield was high as well (Table 1). This result suggested that

Table 1
Dry Matter Yield of Plants Harvested at Different Stubble Heights (Fuhong992)

Date	Treatment	L-Y (kg/ha)	S-Y (kg/ha)	T-Y (kg/ha)
20/7	60	2381.64[a]	3163.44[a]	5545.08[a]
	90	1679.05[b]	2892.50[b]	4571.55[b]
	120	1173.98[c]	2182.59[c]	3356.57[c]
5/9	60	1681.33[c]	2285.98[c]	3967.31[b]
	90	2764.63[a]	4735.94[a]	7500.57[a]
	120	2066.82[b]	3712.09[b]	5778.91[c]
20/10	60	1551.84[b]	1464.93[c]	3016.77[b]
	90	1658.18[a]	2213.59[a]	3871.77[a]
	120	1223.65[c]	1873.22[b]	3096.87[b]

Leaf yield (LY), stem yield (SY), total yield (TY)
[a, b, c] Significant difference at $P<0.05$

harvesting according to stubble height did not reduce the nutritional value of kenaf. Thus, kenaf can be harvested according to stubble height.

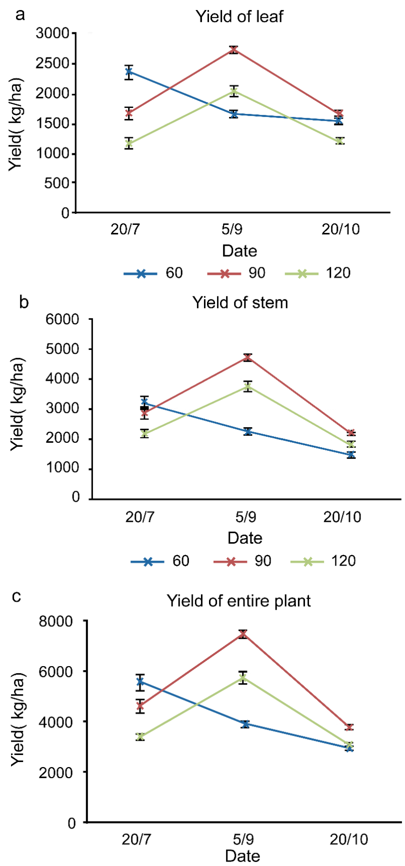

Figure 2. Dry matter yield of leaves (a), stems (b) and the entire plant (c) during the three treatments

Quality Traits of Plants Harvested at Different Stubble Heights

The nutritive components of the whole plants are shown in Table 2. Except for CF (Liu et al., 2014), the nutritive components of the different treatments were significantly different, indicating that stubble height was significantly correlated with the nutritive value of kenaf; this finding is similar to that of previous studies (Huo et al., 2001; Wang & Zhao, 2008).

For the same treatment, the content of CF, CP and EE were different during the first two harvests; the CP and EE content of the third harvest were higher than those of the first two harvests, whereas the CF content was lower than that of the first two harvests (Figures 3 a, b, c). These findings can be attributed to the retarded growth of plants during the third harvest, when the climate was cold. The content of ash, Ca and P were almost the same during the three harvest times, indicating that climate or plant maturity mainly had a significant effect on the CP, EE and CF content, consistent with the findings of previous studies (Chantiratikul et al., 2009; Reta-Sánchez et al., 2010).

Thus, different stubble heights and multiple harvesting times have a significant effect on the nutritive components of kenaf.

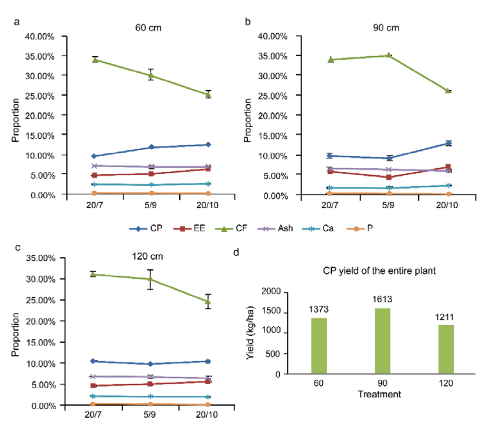

Figure 3. Nutrient content of the different harvest times (a, b and c) for the three trial groups. (d) Crude protein yield of the three treatments

Table 2
Nutrient Content of the Whole Plant of Kenaf Harvested at Different Stubble Heights (Fuhong992)

Date	Treatment	CP (g/kg)	EE (%)	CF (%)	Ash (%)	Ca (%)	P (%)
20/7	60	95.70[b]	4.58[b]	34.06[a]	7.01[a]	2.29[a]	0.18[c]
	90	97.00[b]	5.58[a]	33.25[a]	6.44[b]	1.76[b]	0.17[a]
	120	101.30[a]	4.28[c]	30.91[a]	6.53[b]	1.88[c]	0.14[b]
5/9	60	117.70[a]	5.03[a]	30.14[a]	6.86[a]	2.21[a]	0.15[a]
	90	90.00[b]	4.38[c]	30.28[a]	6.23[b]	1.79[b]	0.14[a]
	120	95.90[c]	4.76[b]	29.88[a]	6.49[ab]	1.88[b]	0.12[a]
20/10	60	124.30[a]	6.34[b]	25.26[a]	6.85[a]	2.57[a]	0.08[c]
	90	127.90[a]	6.85[a]	25.55[a]	6.01[b]	2.33[b]	0.09[a]
	120	102.30[b]	5.50[c]	24.56[a]	6.32[b]	1.77[c]	0.09[b]

Crude protein (CP), ether extract (EE), crude fibre (CF), calcium (Ca) and total phosphorus (P).
[a, b, c] Significant difference at $P<0.05$.

Previous studies used the DM yield and CP content as the reference to evaluate the nutritive value of forage grass (Wang & Zhao, 2008; Wang et al., 2015). In our study, the stubble height of the 90-cm trial group had the highest DM yield (15,943.89 kg/ha) and CP content (1,613 kg/ha; Table 1 and 3d). The DM yield and CP content obtained in this study were higher than those reported previously (Chantiratikul et al., 2009; Reta-Sánchez et al., 2010).

Thus, the stubble harvest method can improve the biomass and nutritive value of kenaf as forage. For further analysis, the stubble height of 90 cm was selected as the most appropriate height for harvest.

The Nutritive Value of Seven Kenaf Varieties

Yield traits of the seven varieties. The DM yield of the different varieties was significantly different at each harvest. The DM yield in the two varieties containing entire leaves was not significantly different from that of the other varieties containing divided leaves (Table 3). Further, the DM yield was not significantly different across different leaf shapes. The DM yield of all seven varieties was the highest during the second harvest, indicating that the climate of the second growth stage was very suitable for the regrowth of kenaf. Except for varieties SZHP35-44 (B) and SZHP35 (D), all the other varieties had the lowest DM yield in the third harvest, which was mainly because of the cold climate.

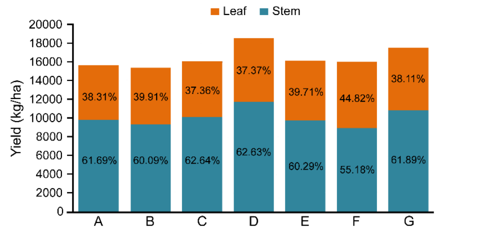

Figure 4. Yield partitioning of the leaves and stems of the seven varieties; Fuhong992, SZHP35-44, H1301, SZHP35, 14-514, 4A-4B and 991FN3 marked as A, B, C, D, E, F and G, respectively

Generally, high DM yield indicates a high proportion of stem. The SZHP35 (D) variety had the highest DM yield (18,502.18 kg/ha) because it had the highest stem yield (11,587.96 kg/ha); however, this finding was not consistent across all the varieties that had a high stem proportion probably because of the differences in germplasms of the different materials (Figure 4).

Leaf yield and biomass are important factors for selecting kenaf cultivars for forage production because leaves are the primary source of protein (Webber, 1993). Variety 4A-4B (F) had the highest leaf output and yield (44.82%), indicating that this variety had higher nutritive value per unit mass. The second-highest proportion and yield of leaves was noted in variety SZHP35 (D) (Figure 4).

The total yield for the seven varieties was more than 15,000 kg/ha (Table 3), which was higher than that reported in previous studies (Chantiratikul et al., 2009; Liang et al., 2003; Reta-Sánchez et al., 2010). Thus, the seven varieties used in this study have the highest yield potential.

Quality traits of the seven varieties. The nutritive components of all the varieties during the first two harvest times were different (Table 4). The CP and Ca content was higher, CF and TP content was lower and ash and EE content was unchanged during the third harvest time than during the first two harvest times owing to the cold climate during the third harvest.

The nutritive components of the seven varieties were significantly different during the same harvest time. Variety 4A-4B (F) had significantly higher CP and lower CF content than the other varieties during the three harvest times. Generally, forage grass with high nutritive value has higher CP content and lower CF content (Chen et al., 2012a; Xiang et al., 2008; Zhu et al., 2014); thus, variety 4A-4B (F) has high potential for use as forage grass.

Table 3
Dry Matter Yield of the Seven Varieties of Kenaf

	L-S (D/E)	1st (kg/ha)	2nd (kg/ha)	3rd (kg/ha)	T-Y (kg/ha)
A	Divided	4,312.63[c]	7,536.28[c]	3,905.29[d]	15,754.20[d]
B	Divided	3,219.53[e]	8,613.30[b]	3,526.48[e]	15,359.31[e]
C	Divided	5,513.85[a]	5,943.80[e]	4,660.53[a]	16,118.19[c]
D	Divided	3,687.11[d]	10,282.01[a]	4,533.06[b]	18,502.18[a]
E	Entire	4,920.18[b]	7,280.93[d]	3,905.83[d]	16,106.94[c]
F	Entire	4,383.83[c]	7,608.90[c]	4,056.90[c]	16,049.63[c]
G	Divided	4,891.89[b]	8,648.64[b]	3,912.11[d]	17,452.64[b]

Leaf shape (LS), Leaf yield (LY), Stem yield (SY), Total yield (TY).
*[a, b, c, d, e] Significant difference at $P<0.05$.
Fuhong992, SZHP35-44, H1301, SZHP35, 14-514, 4A-4B, and 991FN3 marked as A, B, C, D, E, F, and G, respectively

Table 4
Nutritive Components of the Seven Varieties

Variety	CP (k/kg)			EE (%)			CF (%)		
	1	2	3	1	2	3	1	2	3
A	91.40^{f}	89.90^{c}	127.90^{b}	5.58^{b}	4.38^{bc}	6.85^{a}	33.25^{c}	34.28^{ab}	25.55^{a}
B	110.80^{b}	111.70^{a}	128.30^{b}	4.75^{d}	4.24^{c}	5.80^{b}	31.56^{e}	29.72^{c}	20.93^{b}
C	101.20^{c}	105.90^{b}	120.50^{c}	5.12^{c}	5.26^{a}	6.45^{a}	34.13^{b}	33.49^{ab}	20.88^{b}
D	110.30^{b}	104.90^{b}	119.30^{c}	5.59^{b}	5.00^{ab}	4.57^{c}	32.75^{d}	31.82^{bc}	20.13^{b}
E	97.20^{d}	95.00^{c}	158.90^{a}	5.43^{bc}	5.3^{1a}	6.70^{a}	34.42^{b}	34.18^{ab}	21.04^{b}
F	115.20^{a}	111.60^{a}	162.30^{a}	7.15^{a}	4.40^{bc}	5.64^{b}	30.50^{f}	29.71^{c}	16.71^{c}
G	94.30^{e}	94.50^{c}	160.10^{a}	4.23^{e}	5.57^{a}	5.88^{b}	37.43^{a}	36.06^{a}	20.41^{b}
Variety	Ash (%)			Ca (%)			P (%)		
	1	2	3	1	2	3	1	2	3
A	6.44^{ab}	6.23^{a}	6.01^{d}	1.76^{c}	1.79^{d}	2.33^{e}	0.17^{a}	0.14^{b}	0.09^{b}
B	6.16^{c}	6.19^{a}	6.64^{c}	2.03^{b}	2.11^{c}	2.35^{e}	0.16^{ab}	0.13^{c}	0.10^{a}
C	6.45^{ab}	6.26^{a}	6.71^{c}	2.18^{b}	2.13^{c}	3.29^{b}	0.13^{d}	0.12^{cd}	0.09^{b}
D	6.56^{a}	6.46^{a}	6.13^{d}	2.19^{b}	2.14^{c}	3.38^{ab}	0.16^{ab}	0.12^{a}	0.09^{b}
E	6.35^{b}	6.37^{a}	7.88^{b}	2.54^{a}	2.62^{a}	3.39^{a}	0.10^{e}	0.12^{cd}	0.09^{b}
F	6.51^{a}	6.54^{a}	8.66^{a}	2.43^{a}	2.38^{b}	3.16^{c}	0.13^{cd}	0.13^{bc}	0.09^{b}
G	5.58^{d}	5.68^{b}	7.85^{b}	2.44^{a}	2.46^{ab}	2.44^{d}	0.15^{bc}	0.11^{d}	0.08^{c}

Please refer to Table 2 for abbreviations
*$^{a, b, c, d, e}$ Significant difference at P<0.05.
Fuhong992, SZHP35-44, H1301, SZHP35, 14-514, 4A-4B and 991FN3 marked as A, B, C, D, E, F, and G, respectively

The EE and ash content of the varieties were at an average level compared with the corresponding content reported previously (Chantiratikul et al., 2009), whereas Ca and P content was lower than the normal level; these findings could be attributed to the method of de-enzyming (Zhu et al., 2014). Future studies need to focus on improving the de-enzyming method to reduce the loss of mineral elements.

The CP content of the seven varieties of kenaf ranged from 1,571 kg/ha to 2,026 kg/ha and was significantly different across the varieties, while variety SZHP35(D) had the highest CP yield (2,027 kg/ha) (Figure 4).

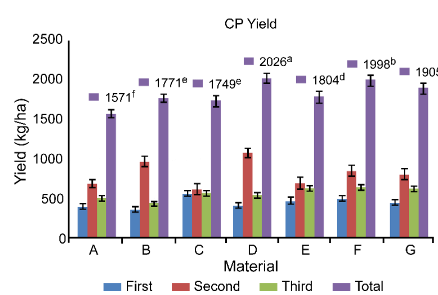

Figure 5. The total crude protein yield of the seven varieties during the three harvest times; Fuhong992, SZHP35-44, H1301, SZHP35, 14-514, 4A-4B and 991FN3 marked as A, B, C, D, E, F and G, respectively

Correspondence Analysis for Yield and Quality Traits

Generally, leaf, stem and entire plant yields are considered as yield traits, while nutritive components are considered as quality traits. Correspondence analysis is used to determine the relationship between trait points and varieties (Liu et al., 2011). In this study, nine traits and seven varieties of kenaf were subjected to correspondence analysis using the SAS 9.2 statistical software.

The results showed that the contribution of the first two Eigen values was 99.85%, while the contribution rate of the first Eigen value was 99.29%, indicating that the first dimension can explain 99.29% of the total information; thus, the data analysis was mainly based on the first dimension (Table 5).

The factor loading of LY was larger than that of SY and TY in the first dimension, suggesting that LY had a higher impact on the yield traits. The factor loading of CP, EE and Ca were larger than those of the other nutritive traits; therefore, these three traits were considered to have an important impact on the nutritive content of kenaf varieties, as has been revealed previously (Wang et al., 2010) (Table 6).

The closer the distance between the variety point and trait point, the higher the possibility that the variety has the trait, which can be an important characteristic (Chen et al. 2012b). The point of F variety

Table 5
Inertia and Chi-Square Decomposition of the Correspondence Analysis

Inertia and Chi-Square Decomposition				
Singular value	Principal inertia	Chi-square	Percent	Cumulative percent
0.03497	0.00122	280.949	99.29	99.29
0.00261	0.00001	1.567	0.55	99.85
0.00110	0.00000	0.280	0.10	99.95
0.00068	0.00000	0.107	0.04	99.98
0.00042	0.00000	0.041	0.01	100.00
0.00009	0.00000	0.002	0.00	100.00
Total	0.00123	280.947	100.00	

Table 6
R Factor Loading of the Correspondence Analysis

Row coordinates		
	Dim1	Dim2
LY	0.0615	-0.0001
SY	-0.0397	-0.0001
TY	0.0000	-0.0001
CP	0.0828	0.0257
EE	0.0482	0.0793
CF	-0.0225	0.0762
Ash	0.0351	0.0437
Ca	0.0705	0.0190
P	-0.0003	-0.0598

was closer to those of LY and CP, suggesting that F variety had higher CP and LY than the other varieties. The points for Fuhong992 (A), SZHP35-44 (B), H1301 (C), SZHP35 (D), 14-514 (E), 4A-4B (F) and 991FN3 (G) varieties were closer to those of SY and TY, suggesting that these varieties had higher biomass than variety 4A-4B(F). The CF point was distant from all the variety points, indicating that these varieties did not have sufficient CF content (Figure 6), but this result needs to be considered with caution, as no other crops were used as negative controls.

The points for EE, Ca, CP and ash were closer and formed a character group, suggesting that these traits were significantly correlated. The point for P was far from the points for the four above-mentioned traits, which was slightly different from the findings of a previous study (Wang et al., 2010); this discrepancy in findings could be attributed to the difference in the sample processing and measurement methods (Figure 6).

A dendrogram obtained using the average linkage clustering based on nutritive and yield traits is shown in Figure 7. Varieties Fuhong992 (A) and SZHP35-44 (B) can be classified into one cluster, and H1301 (C), 14-514 (E) and 991FN3 (G), into another cluster. The distance between the two clusters is small because all of the five varieties can take the stem yield and total yield as their representative traits compared with other nutritive and yield traits. Variety SZHP35 (D) can be classified into one cluster, because its total yield and CP yield were the highest among the seven varieties. Variety 4A-4B (F) was classified into one cluster because it had the highest leaf yield, and its representative traits included CP, which was different from that of the other six varieties. These findings are consistent with the analysis results shown in Tables 3, 4 and 6 and Figure 4.

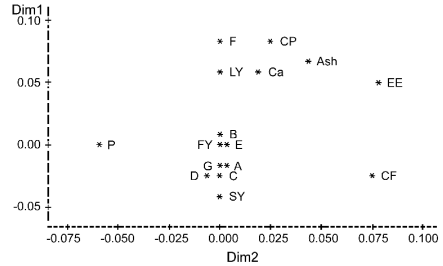

Figure 6. Correspondence analysis chart based on yield and quality traits; Fuhong992, SZHP35-44, H1301, SZHP35, 14-514, 4A-4B and 991FN3 marked as A, B, C, D, E, F and G, respectively

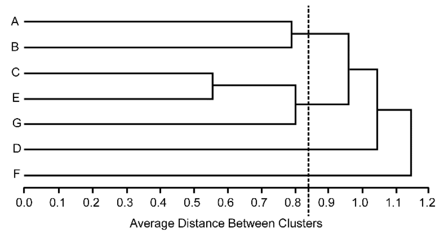

Figure 7. Dendrogram developed using average linkage clustering based on the nutritive traits of the seven varieties; Fuhong992, SZHP35-44, H1301, SZHP35, 14-514, 4A-4B and 991FN3 marked as A, B, C, D, E, F and G, respectively

CONCLUSION

The results of our trial analysis revealed that the stubble height of 90 cm was the most suitable for harvesting kenaf because this trial group had higher DM yield and CP yield than the other two treatments. Variety SZHP35 had the highest CP content. Variety 4A-4B was found to have great potential to be cultured as a forage crop because of its high leaf yield, high CP content and low CF content. SZHP35 can be considered forage material based on its total yield and nutritive value, while 4A-4B can also be good forage material owing to its high leaf yield. Therefore, both the varieties are good for feed utilisation.

Kenaf can be harvested multiple times in one growing season depending on stubble height to ensure sustainable yield. The kenaf varieties had average yield equal to that of alfalfa, which is a high biomass material; therefore, the high nutritive value of kenaf allows it to be used as an excellent non-grain-based protein-rich feed resource.

Although tender plants have high CP content, their DM yield is low. This suggests that stubble height and harvest time need to be further optimised. Since leaf proportion is an important factor in improving leaf yield, future research should focus on the relationship between leaf shape and leaf yield.

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