Growth, Hay Yield and Chemical Composition of Cassava and Stylo 184 Grown under Intercropping

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ABSTRACT : The objective of this field experiment was to investigate the growth, hay yield and chemical composition of cassava and stylo 184 grown under intercropping. The experiment was arranged in a Randomized Complete Block (RCB) design with 5 treatments and 4 replications. The treatments were: sole crop cassava (C); sole crop stylo 184 (S) and three intercropping treatments comprising an additive series of one (SC), two (SSC) and three (SSSC) rows of stylo 184 to one row of cassava. The results showed that leaf area per plant (LA) of cassava was significantly higher ($p<0.05$) in the sole crop relative to the intercropping treatments. Both total hay yield and CPDM yield were significantly higher ($p<0.05$) for C treatment and lower ($p<0.05$) for SSSC treatment. The total hay yield and CPDM yield were significantly greater ($p<0.05$) in the sole crop relative to the intercropping treatments. At the first and second harvests, CP content was similar among treatments; while at third and fourth harvests, CP contents were significantly greater ($p<0.05$) for the intercropping treatment relative to the sole crop. At the first and second harvest, NDF contents were significantly greater ($p<0.05$) in the sole crop relative to the intercropping treatments, whereas NDF contents were similar among intercropping treatments. Leaf area of stylo 184 at first and second harvest were significantly greater ($p<0.05$) for C, SC and SSC as compared with the SSSC treatments. At each harvesting, there were no significant differences in ash, CP, NDF, ADF and ADL contents of stylo 184 hay between the sole crop and intercropping treatments, except for the first harvest. ADF contents were significantly greater ($p<0.05$) in S, SC treatments relative to SSC and SSSC treatments. Both collective hay yield and CPDM yield of cassava and stylo 184 were significantly greater ($p<0.05$) for the SSC treatment and significantly lower ($p<0.05$) for the S treatment. Collective hay yield and CPDM yield were significantly greater ($p<0.05$) for the intercropping treatments relative to the sole crop. Based on this research, it was concluded that stylo 184 showed potential for intercropping with cassava. Intercropping cassava with stylo 184 has beneficial effects and can improve foliage biomass yield and soil fertility, which would be a more sustainable system than growing the cassava as a pure stand. In terms of hay yield and CP production, two rows of stylo 184 to one row of cassava could be the optimal pattern for this intercropping system. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 6 : 799-807)***

Key Words : Cassava, Stylo 184, Growth, Hay Yield, Chemical Composition, Intercropping

INTRODUCTION

Cassava or tapioca (*Manihot esculenta*, Crantz*)* is an annual tuber crop grown widely in tropical and sub-tropical areas. It can thrive in sandy-loam soil with low organic matter, receiving low rainfall and high temperatures. It is therefore a cash crop cultivated by small-holder farmers within the existing farming systems in many countries (Wanapat, 1999). Cultivation of cassava biomass to produce hay at three months after planting and followed every one to two months thereafter until one year, produced a collective DM yield of 11,786 kg/ha (Wanapat et al., 2002). Cassava hay contains a high level of crude protein (24.9%) (Wanapat et al., 1997).

The potential advantages of intercropping are well documented (Willey, 1979a,b; Vandermeer, 1989). In situations where intercropping has led to higher yields than sole cropping, advantages have often been attributed to the component crops complimenting each other in their use of resources (Willey, 1979a,b; Vandermeer, 1989; Tournebize and Sinoquet, 1995). In general, intercropping has been shown to be more productive than monocropping. However, combinations of certain crops result in increased competition among the components. This results in reduced yields, which may make some crop species unsuitable for intercropping. There may be increased competition for water, nutrients, light or any combination of the three, ultimately leading to changes in crop productivity levels. Changes in crop development can be examined by investigating the manner in which yield components are affected by alterations in cropping patterns (Carruthers et al., 2000). Sole crop of cassava alone could possibly lead to deterioration of soil fertility after several years of plantations (Polthanee, 1999). The legume crops have been considered to be the suitable crops for use intercropping pattern with cassava. They could possibly be used in improving soil fertility through its root nitrogen fixation and crop residues (Suksri, 1993). Ashokan et al. (1985) also reported that they could possibly be used in improving soil fertility through its root nitrogen fixation and crop residues. Intercropping cassava with a leguminous crop such as cowpea could improve soil fertility and provide food for human consumption and the residue used as supplemental

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Table 1. Designation of the treatments, plant spatial arrangements and population density

Treatment	Row-spacing (cm)		Intra-row spacing (cm)		Population (plants/ha)	
	Cassava	Stylo 184	Cassava	Stylo 184	Cassava	Stylo 184
C[1]	100	-	30	-	32,432	-
S	-	100	-	30	-	32,432
SC	100	50-50	30	30	32,432	21,622
SSC	100	30-40-30	30	30	32,432	43,244
SSSC	100	30-20-30	30	30	32,432	64,866

[1] Sole cassava (C), sole stylo 184 (S), single (SC), double (SSC) and and triple (SSSC) row stylo 184/cassava intercropping.

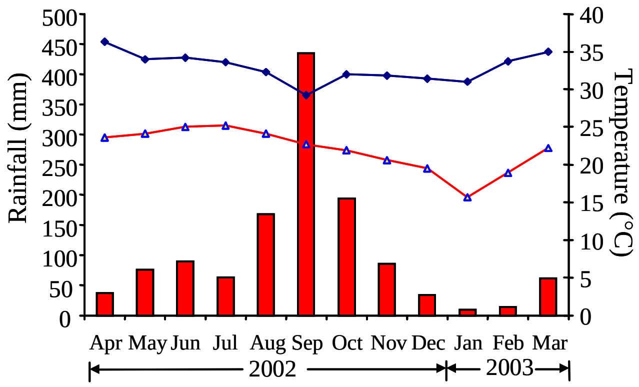

Figure 1. Monthly weather data during the experimental period: rainfall is shown by the colums; minimum temperature Δ-Δ; maximum temperature ♦-♦. Source: Thapra Meteorological Station, Khon Kaen (2003).

feed especially during the dry season (Polthanee et al., 2001). *Stylosanthes guianensis* CIAT 184, commonly known as "stylo 184" (Horne and Stur, 1999), is at the present time widely used in tropical countries (Mannetje and Jones, 1992). Stylo 184 was introduced to Thailand in 1993 to evaluate growth and biomass yield, planted at 50× 30 cm spacing between rows and plants. It was found that it could grow well and produce 12-17 t DM yield/ha/year with 14-18% CP and could be preserved as hay with high palatability for ruminants (Satjipanon et al., 1995).

The objective of this experiment is to study growth, hay yield and chemical composition of cassava and stylo 184 grown under intercropping.

MATERIALS AND METHODS

Location and climate of the experimental site

The field experiment was conducted under rainfed conditions during April 2002 - February 2003 at Khon Kaen Animal Nutrition Research and Development Center, Khon Kaen, in Northeast Thailand (16.2°N, 102.5°E; 166 m above sea level). The monthly weather data of rainfall, average maximum and minimum temperatures throughout the growing season are shown in Figure 1.

Experimental design and treatments

The experimental layout was a Randomized Complete Block (RCB) design with four replications. The experiment comprised of five treatments: sole crop cassava (C); sole crop stylo 184 (S) and three intercropping treatments comprising an additive series of one (SC), two (SSC) and three (SSSC) rows of stylo 184 to one row of cassava. The treatments applied in the experiment are shown in detail in Table 1.

Crop cultivation

Individual plot size was 5.0×8.0 m. Rows were orientated in east-west direction in order to maximise the degree of mutual shading experienced by component intercrops. One-month-old seedlings of *Stylosanthes guianensis* CIAT 184 and stems of cassava variety "Rayong 72" were planted on May 19, 2002 at spacing according to the respective treatments (Table 1). Two weeks prior to planting, dolomite was incorporated into all treatments at the rate of 625 kg/ha. A basal complete fertilizer (188, 188, 188 kg/ha of N, P and K, respectively) was applied at planting, with an additional application of triple superphosphate (125 kg/ha of P) in early July 2002, which in accordance with the Department of Livestock Development (2001). The entire plot area was kept weed-free with hand hoeing at 20 and 75 days after planting and whenever necessary.

Data collection and plant harvesting

All records were taken from the inner 3.0×7.4 m area of each plot in order to minimize the effect of border row. Four harvests (1st harvest: August 19, 2002; 2nd harvest: October 19, 2002; 3rd harvest: December 19, 2002 and 4th harvest: February 19, 2003) were carried out during the experimental period by harvesting the first time at 3 months after planting and followed by every 2 months until it reached 10 months. In intercropping treatments, the harvested plant biomass was separated into two portions, cassava and stylo 184. Both forage samples from each plot were weighed. Plots were harvested individually.

Cassava was harvested by breaking the stem at approximately 10 cm above the ground level in accordance with Wanapat et al., 1997; Wanapat et al., 2000, 2003. A sub-sample of approximately 500 g was collected from each plot and dried in a forced-air oven (60°C) for 48 h to determine forage DM, which was used to calculate DM yield. Subsamples were prepared for quality analysis by

Table 2. Leaf area per plant of cassava sole crop and cassava-stylo 184 intercropping patterns (cm^2)

Treatment	Harvesting			
	1st	2nd	3rd	4th
C	125^a	109^a	72^a	61^a
SC	90^b	69^b	28^b	20^b
SSC	74^b	62^b	31^b	21^b
SSSC	83^b	69^b	34^b	23^b
Significance	*	*	*	*
CV (%)	16.8	15.0	12.7	13.6

[a, b] Means with different superscripts in the same row are significantly different (p<0.05). * p<0.05. CV: coefficient of variation.
Sole cassava (C), single (SC), double (SSC) and and triple (SSSC) row stylo 184/cassava intercropping.

grinding with a Wiley mill to pass through a 1 mm screen.

Stylo 184 was harvested by cutting at approximately 10 cm above the ground level in accordance with the Department of Livestock Development (2001). A sub-sample of approximately 500 g was collected from each plot and dried in a forced-air oven (60°C) for 48 h to determine forage DM, which was used to calculate DM yield. Subsamples were prepared for quality analysis by grinding with a Wiley mill to pass through a 1 mm screen.

At each harvest, the leaf area was measured using a leaf area meter (Model No. AAC-400, Hayashi Denko Co., Ltd. Japan). Two plants in C and S treatments; two cassava and one, two and three stylo 184 plants located at the same line in SC, SSC and SSSC treatments were randomly selected for leaf area measurement. Soil samples were taken from 10 locations within each plot at 0-15 cm depths prior to the experiment and after the 4th harvest as following. For C and S, the point of sampling were between rows and plants; For SC, SSC and SSSC the point of sampling were between rows and plants of cassava and stylo 184. The samples collected from each plot were shade dried, crushed and sieved through a 2 mm mesh before being analyzed for major nutrients.

Chemical analyses and calculation of secondary attributes

At each harvest, sub-samples of cassava and stylo 184 were analysed for dry matter (DM), ash and nitrogen (Kjeldahl-N) by the AOAC (1990) procedures. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (ADL) were determined by the methods of Van Soest and Robertson (1991). In addition, samples of cassava were analyzed for condensed tannins (CT) using the vanillin-HCl method (Burns, 1971 as modified by Wanapat and Poungchompu, 2001). Samples of soil collected prior to experiment were analyzed for pH, total nitrogen (N), organic matter (OM), phosphorous (P), potassium (K), calcium (Ca) and magnesium (Mg); collected after the 4th harvest were analyzed for total N. Soil pH was determined with a digital pH meter, total N content by Kjeldahl method, P by vanadomolybdate methods, K by flame photometry, Ca and Mg by atomic absorption spectrophotometry. Sample analysis was carried out in the Animal Nutrition Laboratory of the Khon Kaen Animal Nutrition Research and Development Center and the Ruminant Nutrition Laboratory of the Department of Animal Science, Faculty of Agriculture, Khon Kaen University. The leaf area per plant was obtained by calculation: leaf area per plant (LA) =total leaf area of plant measured/number of plants measured. Further parameters were calculated as follows: the content of crude protein (CP)=N×6.25;Dry matter yield (DMY)=fresh forage yield×%DM; Dry matter crude protein yield (CPDMY)=DMY×%CP.

Statistical analyses

The various data were subjected to the analyses of variance (ANOVA) procedure for Randomised complete block design experiments using the general linear models (GLM) of the SAS System for Windows (SAS 6.12, TS level 020, SAS Institute, 1998). Probabilities less than 0.05 were considered significant. Treatment means were compared using Duncan's New Multiple Range test (Steel and Torries, 1980). The statistical model is

$$y_{ij}=m+tx_i+bl_j+e_{ij}$$

where m is the grand mean, tx_i the *i*th treatment effect, bl_j the *j*th block effect, and e_{ij} is the experimental error of treatment *i* in block *b*.

RESULTS

Weather conditions and soil characteristics

Rainfall was evenly distributed in the wet season (May-September, 2002). Total precipitation during the experimental period (April, 2002-February, 2003) was 1,266.1 mm. Monthly average maximum and minimum temperature ranged from 29.2 to 36.3 and 15.7 to 25.2°C, respectively. The heaviest rainfall occurred in September, which is the time of the growing stage of cassava and stylo 184.

The soil type on which the present study was conducted was an Oxic Paleustults of order Ultisol. Mean values of initial soil analysis were 5.2 for pH, 0.04 % for total N, 28.9 ppm for available P, 39.1 ppm for exchangeable K, 169.3 ppm for Ca, 32.0 ppm for Mg and 0.53% organic matter content. The soil was a sandy clay loam in texture.

Cassava leaf area per plant

Leaf area per plant (LA) of cassava is presented in Table 2. At each harvest, LA was significantly greater (p<0.05) in the sole crop relative to the intercropping treatments, whereas LA was not significantly different among

Table 3. Hay yield and CPDM yield of cassava sole crop and cassava-stylo 184 intercropping patterns (t/ha)

Treatment	Harvesting				Total
	1st	2nd	3rd	4th	
Hay yield, DM t/ha					
C	2.3[a]	1.5[a]	0.6[a]	0.1	4.5[a]
SC	1.5[b]	1.1[b]	0.4[b]	0.1	3.1[b]
SSC	1.3[b]	1.0[b]	0.3[b]	0.1	2.7[b]
SSSC	1.1[c]	0.7[c]	0.2[b]	0.1	2.1[c]
Significance	*	*	*	NS	*
CV (%)	20.2	10.5	13.8	15.4	19.9
CP yield, DM t/ha					
C	0.5[a]	0.3[a]	0.1	0.03	0.93[a]
SC	0.3[b]	0.2[b]	0.1	0.03	0.63[b]
SSC	0.3[b]	0.2[b]	0.1	0.03	0.63[b]
SSSC	0.2[c]	0.1[c]	0.1	0.03	0.43[c]
Significance	*	*	NS	NS	*
CV (%)	23.6	12.5	15.4	13.7	16.7

[a, b, c] Means with different superscripts in the same row are significantly different ($p<0.05$). * $p<0.05$.
NS: values are not significantly different ($p>0.05$). CV: coefficient of variation. [1] DM: dry matter, CP: crude protein.
Sole cassava (C), single (SC), double (SSC) and triple (SSSC) row stylo 184/cassava intercropping.

Table 4. Chemical composition of cassava hay sole crop and cassava-stylo 184 intercropping patterns

Treatment	Ash	CP	NDF	ADF	ADL	CT
Chemical composition (% DM), 1st harvest						
C	7.5	21.6	48.9[a]	37.4[a]	15.3	3.4
SC	6.8	21.5	47.5[b]	32.5[b]	14.9	3.6
SSC	7.4	22.9	45.7[b]	32.2[b]	13.4	3.4
SSSC	7.7	21.3	47.2[b]	30.9[b]	14.2	3.2
Significance	NS	NS	*	*	NS	NS
CV (%)	20.3	22.2	21.7	20.3	19.9	14.3
Chemical composition (% DM), 2nd harvest						
C	6.6	21.9	50.3[a]	35.4	13.8	3.5
SC	6.1	20.9	45.5[b]	34.8	14.0	3.8
SSC	6.1	21.9	45.1[b]	31.9	12.8	3.3
SSSC	6.3	20.7	45.3[b]	33.8	13.5	3.0
Significance	NS	NS	*	NS	NS	NS
CV (%)	25.3	27.2	21.5	20.3	19.6	13.6
Chemical composition (% DM), 3rd harvest						
C	6.3	21.9[a]	44.7	31.1[a]	13.5[a]	3.9
SC	5.9	25.5[b]	45.5	32.7[b]	15.3[b]	3.7
SSC	6.2	25.8[b]	44.8	29.7[c]	13.4[a]	3.3
SSSC	5.3	25.6[b]	44.9	27.9[d]	13.6[a]	3.2
Significance	NS	*	NS	*	*	NS
CV (%)	22.0	22.9	21.7	20.4	19.7	17.3
Chemical composition (% DM), 4th harvest						
C	6.0	21.8[a]	44.8	31.2[a]	13.6[a]	3.4
SC	6.1	25.5[b]	45.5	32.8[b]	15.4[b]	3.6
SSC	6.2	25.7[b]	44.7	29.5[c]	13.6[a]	3.4
SSSC	5.4	25.7[b]	44.7	27.8[d]	13.4[a]	3.7
Significance	NS	*	NS	*	*	NS
CV (%)	19.7	21.2	30.1	20.3	17.9	19.6

[a, b, c, d] Means with different superscripts in the same row are significantly different ($p<0.05$). * $p<0.05$.
NS: Values are not significantly different ($p>0.05$). CV=coefficient of variation.
[1] DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, ADL: Acid detergent lignin, CT: condensed tannins.
Sole cassava (C), single (SC), double (SSC) and triple (SSSC) row stylo 184/cassava intercropping.

intercropping treatments. Intercropping with stylo 184 had a significant effect on LA and growth in cassava. As compared with sole cropping, LA and growth was reduced.

Cassava hay yield and CPDM yield

Hay and crude protein dry matter (CPDM) yields of all treatments at first harvest were greater than those in the second, third and fourth harvest, respectively. Both total hay

Table 5. Leaf area per plant of stylo 184 sole crop and cassava-stylo 184 intercropping patterns (cm^2)

Treatment	Harvesting			
	1st	2nd	3rd	4th
S	57[a]	56[a]	24	22
SC	54[a]	52[a]	22	20
SSC	56[a]	56[a]	20	21
SSSC	45[b]	35[b]	20	22
Significance	*	*	NS	NS
CV (%)	14.8	16.0	12.2	15.6

[a, b] Means with different superscripts in the same row are significantly different (p<0.05). * p<0.05.
NS: values are not significantly different (p>0.05).
CV: coefficient of variation.
Sole stylo 184 (S), single (SC), double (SSC) and and triple (SSSC) row stylo 184/cassava intercropping.

Table 6. Hay yield and CPDM yield of stylo 184 sole crop and cassava-stylo 184 intercropping patterns (t/ha)

Treatment	Harvesting				Total
	1st	2nd	3rd	4th	
Hay yield, DM t/ha					
S	1.6 [bc]	1.4[a]	0.4[a]	0.25[a]	3.65[a]
SC	0.8[a]	1.0[b]	0.5[a]	0.08[b]	2.38[b]
SSC	1.8[b]	1.7[c]	0.8[b]	0.13[c]	4.43[c]
SSSC	1.5[c]	1.5[a]	0.5[a]	0.14[c]	3.64[a]
Significance	*	*	*	*	*
CV (%)	27.2	20.5	17.8	15.4	17.9
CP yield, DM t/ha					
S	0.3[a]	0.2[a]	0.1	0.05[a]	0.65[a]
SC	0.1	0.2[a]	0.1	0.01[b]	0.41[b]
SSC	0.3[a]	0.3[b]	0.1	0.02[b]	0.72[c]
SSSC	0.3[a]	0.3[b]	0.1	0.03[c]	0.73[c]
Significance	*	*	NS	*	*
CV (%)	20.5	21.5	16.9	15.8	18.9

[a, b, c] Means with different superscripts in the same row are significantly different (p<0.05). * p<0.05.
NS: Values are not significantly different (p>0.05).
CV: coefficient of variation.
[1] DM: dry matter, CP: crude protein.
Sole stylo 184 (S), single (SC), double (SSC) and and triple (SSSC) row stylo 184/cassava intercropping.

and CPDM yields were significantly higher (p<0.05) for treatment C and significantly lower (p<0.05) for treatment SSSC, whereas SC and SSC were not significantly different from each others. The total hay and CPDM yields were significantly greater (p<0.05) in the sole crop relative to the intercropping treatments (Table 3).

Chemical composition of cassava hay

Chemical composition of cassava hay harvested at different times is shown in Table 4. At first and second harvest, CP content was similar among treatments, whereas at third and fourth harvest, CP contents were significantly greater (p<0.05) for the intercropping treatment relative to the sole crop. However, CP contents were not significantly different among intercropping treatments. At first and second harvest, NDF contents were significantly greater (p<0.05) in the sole crop relative to the intercropping treatments, whereas NDF contents were not significantly different among intercropping treatments, but at third and fourth harvest NDF contents were similar among treatments. At first harvest, ADF contents were significantly greater (p<0.05) for the sole crop relative to the intercropping treatments, whereas ADF contents were not significantly different among intercropping treatments, but at second harvest ADF contents were similar among treatments. At third and fourth harvest, ADF contents were significantly greater (p<0.05) for SC treatment and significantly lower (p<0.05) for SSC treatment. At first and second harvest, ADL content was similar among treatments. At third and fourth harvest, ADL content was significantly greater (p<0.05) for SC treatment, whereas ADL contents were not significantly different among C, SSC and SSSC treatments. At each harvesting, there were no significant differences in DM, ash and CT contents of cassava hay between the sole crop and intercropping treatments.

Stylo 184 leaf area per plant

Leaf area per plant (LA) of stylo 184 is presented in Table 5. At first and second harvest, LA were significantly greater (p<0.05) for C, SC, SSC as compared with SSSC treatments, whereas LA was not significantly different among C, SC, SSC treatments. At third and fourth harvest, there were no significant differences in LA of stylo 184 between the sole crop and intercropping treatments.

Stylo 184 yield and CPDM yield

Hay yield and CPDM yield of stylo 184 are shown in Table 6. Total DM yield was significantly greater (p<0.05) for SSC treatment and significantly lower (p<0.05) for SC treatment, whereas S and SSSC were not significantly different from each other. Total CPDM yield was significantly greater (p<0.05) for SSSC treatment and significantly lower (p<0.05) for SC treatment, whereas SSC and SSSC were not significantly different from each other.

Chemical composition of stylo 184 hay

At each harvesting, there were no significant differences in DM, ash, CP, NDF, ADF and ADL contents of stylo 184 hay between the sole crop and intercropping treatments, except that at first harvest ADF contents were significantly greater (p<0.05) in S, SC treatments relative to SSC and SSSC treatments. The ash, CP, NDF, ADF and ADL contents of stylo 184 hay ranged from 5.6 to 9.2, 16.3 to 19.1, 48.0 to 61.5, 33.5 to 47.3 and 7.4 to 10.8%, respectively (Table 7).

Collective hay and CPDM yield of cassava and stylo 184

Collective hay and CPDM yield of cassava and stylo

Table 7. Chemical composition of stylo 184 sole crop and cassava-stylo 184 intercropping

Treatment	Ash	CP	NDF	ADF	ADL
Chemical composition (% DM), 1st harvest					
S	8.7	16.7	60.6	47.3[a]	10.6
SC	9.2	16.7	60.8	45.0[a]	10.5
SSC	8.8	16.3	60.9	42.5[b]	9.8
SSSC	8.8	17.4	60.1	40.0[b]	9.7
Significance	NS	NS	NS	*	NS
CV (%)	22.3	20.2	21.0	24.3	16.3
Chemical composition (% DM), 2nd harvest					
S	6.3	17.2	61.5	43.6	10.4
SC	6.3	16.5	61.4	42.0	10.5
SSC	5.7	17.0	59.0	43.0	10.8
SSSC	5.6	17.1	59.3	40.1	9.9
Significance	NS	NS	NS	NS	NS
CV (%)	20.7	22.6	21.0	24.3	20.3
Chemical composition (% DM), 3rd harvest					
S	6.9	18.1	50.1	34.1	8.0
SC	6.5	17.7	48.0	35.6	7.9
SSC	6.9	17.4	51.6	35.1	7.7
SSSC	6.5	17.1	48.7	33.5	7.4
Significance	NS	NS	NS	NS	NS
CV (%)	27.0	24.2	23.7	20.9	19.1
Chemical composition (% DM), 4th harvest					
S	6.7	18.0	49.1	34.3	7.9
SC	6.9	17.8	48.3	35.5	7.8
SSC	6.5	17.6	51.3	34.7	7.8
SSSC	6.7	17.9	48.5	33.6	7.6
Significance	NS	NS	NS	NS	NS
CV (%)	26.3	29.2	21.7	22.3	22.7

[a, b] Means with different superscripts in the same row are significantly different ($p<0.05$). * $p<0.05$.
NS: Values are not significantly different ($p>0.05$). CV: coefficient of variation.
[1] DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, ADL: Acid detergent lignin.
Sole stylo 184 (S), single (SC), double (SSC) and and triple (SSSC) row stylo 184/cassava intercropping.

Table 8. Collective hay and CP yield of cassava and stylo 184

Treatment	Collective hay yield (t/ha)	
	DM yield	CP yield
C	4.50[a]	0.93[a]
S	3.65[b]	0.65[b]
SC	5.48[c]	1.04[c]
SSC	7.13[d]	1.35[d]
SSSC	5.74[c]	1.16[c]
Significance	*	*
CV (%)	11.7	15.2

[a, b, c, d] Means with different superscripts in the same row are significantly different ($p<0.05$). * $p<0.05$.
CV: coefficient of variation. [1] DM: dry matter, CP: crude protein.
Sole cassava (C), sole stylo 184 (S), single (SC), double (SSC) and and triple (SSSC) row stylo 184/cassava intercropping.

184 are presented in Table 8. Both collective hay and CPDM yield were significantly greater ($p<0.05$) for SSC treatment and significantly lower ($p<0.05$) for S treatment, whereas SC and SSSC were not significantly different from each other. Collective hay and CPDM yield were significantly greater ($p<0.05$) for the intercropping treatments relative to the sole crop.

Soil nitrogen enrichment

Total N content of soil collected after the 4th harvest was significantly higher ($p<0.05$) in S, SC, SSC and SSSC treatments relative to C treatments. The total N content of soil in S, SC, SSC and SSSC treatments prior to the experiment and after the 4th harvest were not different from each other, whereas total N content in the C treatment collected after the 4th harvest was lower as compared to soil in C treatment prior to the experiment (Table 9.)

DISCUSSION

The result indicated that cassava crop had low capacity for competing with stylo 184. This may have been caused by the competition for water, nutrients, light or any combinations of the three, ultimately leading to a reduction of crop productivity levels. When two plants grow near one another, basic physiological principles suggest that they will compete for environmental resources regardless of facilitation. If competition and facilitation are both operative, the net effect could switch from positive to negative as a function of density (Vandermeer, 1990). LA of

Table 9. Soil nitrogen enrichment (% total N)

Treatment	Soil nitrogen (% total N)	
	Prior to the experiment	After the 4th harvest
C	0.0223	0.0166[a]
S	0.0223	0.0224[b]
SC	0.0213	0.0214[b]
SSC	0.0211	0.0210[b]
SSSC	0.0264	0.0266[b]
Significance	NS	*
CV (%)	27.7	30.1

[a, b] Means with different superscripts in the same row are significantly different ($p<0.05$). * $p<0.05$.

NS: values are not significantly different ($p>0.05$).

CV: coefficient of variation.

Sole crop cassava (C), sole crop stylo 184 (S), single (SC), double (SSC) and and triple (SSSC) row stylo 184/cassava intercropping.

all treatments subsequently decreased at harvesting times. Generally, more biomass is produced at an early stage of growth for the plant and decreases as season proceeds. It may also be due to the low rainfall as well as poor distribution in early December 2002 to mid February 2003 September (Figure 1), which was attributed to decreasing leave size in third and fourth harvest.

Hay and CPDM yields of cassava of all treatments were subsequently decreased at harvesting times. Generally, more biomass is produced at an early stage of growth for the plant and decreases as season proceeds. It may also be due to the low rainfall as well as poor distribution in early December 2002 to mid February 2003 September as discussed previously (Figure 1), hay and CPDM yields in third and fourth harvest were decreasing, as shown in Table 3. Intercropping with stylo 184 had significant effect on hay yield, CPDM yield and fresh root yield in cassava. Intercropping reduced hay yield, CPDM yield and fresh root yield as compared with sole cropping.When two plants grow near one another, basic physiological principles suggest that they will compete for environmental resources regardless of facilitation. If competition and facilitation are both operative, the net effect could switch from positive to negative as a function of density (Vandermeer, 1990).

The ash, CP, NDF, ADF, ADL and CT contents of cassava hay ranged from 5.3 to 7.7, 20.7.3 to 25.8, 44.7 to 50.3, 27.8 to 37.4, 12.8 to 15.3 and 3.0 to 3.9%, respectively. CP and CT contents of cassava hay were found in a similar range to those reported by Wanapat et al. (1997). From the results in Table 4, it can also be noted that CP content of cassava hay in intercropping treatments at third and fourth harvest was extremely higher as compared to first and second harvest.

At first and second harvest, stylo 184 of SSSC treatments had the smallest LA, which probably resulted from over population density itself and competition with growth of the cassava plants for the treatment resulting in lower DM yield as compared to C, SC, SSC treatments (Table 6.)

At third and fourth harvest, the results show that stylo 184 plants were capable of competing with cassava for light interception among the crop canopies i.e. shading effect produced by cassava plant height did not affect growth of stylo 184 plants. The results in this study show that stylo 184 grown in intercropping with cassava and sole crop had greater competitive ability compared with cassava grown alone. This indicated that stylo 184 plants had a great ability to adapt themselves to such a highly competitive environment as to compete for radient energy from the sun, hence the biomass of individual plants was able to develop. A similar finding was reported by Polthanee et al. (1999), who found that mungbean plants were able to compete with cassava for light interception among the crop canopies i.e. there was no shading effect produced by cassava plant height, which affected growth of mungbean plants.

The result in this study showed that hay yield of stylo 184 was the highest for SSC treatment and the lowest for SC treatment. This was mainly due to the lower population density for stylo 184 (21,622 plants/ha) in SC treatment. Nevertheless, the SSSC treatment had a higher population density than SSC treatment (64,866 vs. 43,244 plants/ha), but resulted in lower DM yield than SSC treatment. This might be due to competition for water, nutrients, light or any combination of the three, ultimately resulting in reduced yields. This is in accordance with Carruthers et al. (2000), who reported that combinations of certain crops result in increased competition among the components. This results in reduced yields and over-density may make some crop species unsuitable for intercropping.

These results were in agreement with the work by Kiyothong et al. (2002), who reported that CP, NDF, ADF contents of stylo 184 grown at Khon Kaen Animal Nutrition Research and Development Center were found in the range of 15.39 to 21.87, 45.23 to 63.34 and 31.12 to 47.08%, respectively.

The results in this study showed that hay and CPDM yield obtained from one, two and three rows of stylo 184 to one row of cassava treatments were significantly higher ($p<0.05$) than cassava and legume in sole cropping (5.48 and 1.04; 7.13 and 1.35; 5.74 and 1.16; 4.50 and 0.93; 3.65 and 0.65 t/ha, respectively). This was in accordance with the reports of other studies, and the potential advantages of intercropping are well documented (Willey, 1979a,b; Vandermeer, 1989). In situations where intercropping has led to higher yields than sole cropping, advantages have often been attributed to the component crops complimenting each other in their use of resources (Willey, 1979a,b; Vandermeer, 1989; Tournebize and Sinoquet, 1995).

The results in this study showed that stylo 184 could have been responsible for improving soil fertility through its root nitrogen fixation, an effect which can be largely attributed to the increase in total N in the soil. This result was in agreement with Polthanee et al. (2001), who reported that intercropping cassava with leguminous crop such as cowpea could improve soil fertility; Suksri (1993), who reported that the legume crops could possibly be used in improving soil fertility through its root nitrogen fixation and crop residues and Ashokan et al. (1985) who also reported that legume crops could possibly be used in improving soil fertility through its root nitrogen fixation and crop residues. The total N content of soil in the stylo 184-based treatments was stable. The reason could possibly be the N uptake of cassava plants was the same amount of N release.

CONCLUSION AND RECOMMENDATIONS

Based on this research, it was concluded that stylo 184 showed potential for intercropping with cassava. Intercropping cassava with stylo 184 had beneficial effects and improved foliage biomass yield and soil fertility, which would be a more sustainable system than growing the cassava as a pure stand. It is recommended that intercropping two rows of stylo 184 to one row of cassava should be planted together, which gave the highest hay and CPDM yield (7.13 and 1.35 t/ha, respectively). Cassava-stylo 184 hay production could contribute to sustainable livestock-crop production systems in the tropics. As cassava and stylo 184 are perennial crops, experiments in second- and third-year crops need to be further investigated to confirm that this intercropping pattern would still give the highest hay and CPDM yield and in order to provide practical recommendations to small-holder dairy farmers especially those in the tropics.

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REFERENCES

Association of Official Analytical Chemists (AOAC). 1990. 15th ed. Association of Official Analytical Chemists. Washington DC, USA.

Ashokan, P. K., R. Vikraman and K. Sudhadara. 1985. Studies on cassava-legume intercropping systems for the Oxisols of Kerala State, India. Trop. Agric. 62(4):313-318.

Burns, R. 1971. Method for estimatation of tannin in grain sorghum. Agronomy Journal 63:511-512.

Carruthers, K., B. Prithiviraj, Q. Fe, D. Cloutier, R. C. Martin and D. L. Smith. 2000. Intercropping corn with soybean, lupin and forages: yield component responses. Eur. J. Agron. 12:103-115.

Department of Livestock Development 2001. Forage legume information. http://www.dld.go.th.html

Horne, P. M. and W. W. Sturr. 1999. Developing forage technologies with smallholder farmers-how to select the best varieties to offer farmers in Southeast Asia. ACIAR Monograph.

Kiyothong, K., C. Satjipanon and P. Pholsen. 2002. Effect of cutting height and time on seed yield and seed quality of S*tylosanthes guianensis* CIAT 184. Songklanakarin J. Sci. Technol. 24(4):587-593.

Mannetje, L.'t. and R. M. Jones. 1992. Plants Resources of Southeast Asia.No.4 Forages. p. 300.

Polthanee, A. 1999. Studies on Cassava-Peanut Intercropping Patterns in an Acid Soil in Northeast Thailand. Thai J. Agric. Sci. 32(1):127-134.

Polthanee, A., S. Wanapat, M. Wanapat and C. Wachirapakorn. 2001. In: Proc. International Wrokshop on Current research and development of cassava as animal feeds, organized by Khon Kaen University and Swedish International Development Agency (SIDA) and Swedish Agency for Research and Cooperation with Developing Countries (SAREC), July 23-24, Kosa Hotel, Thailand.

Puangchompoo, A., S. Wanapat, A. Polthanee, C. Wachirapakorn and M. Wanapat. 2001. Effect of planting methods, fertilization on cassava hay yield and chemical compositions. In: Proc. International Wrokshop on Current research and development of cassava as animal feeds, organized by Khon Kaen University and Swedish International Development Agency (SIDA) and Swedish Agency for Research and Cooperation with Developing Countries (SAREC), July 23-24, Kosa Hotel, Thailand.

SAS. 1998. User's Guide: Statistics, Version 6.12th Edition. SAS Inst. Inc., Cary, NC.

Satjipanon, C., V. Jinosaeng and V. Susaena. 1995. Forage seed production project for Southeast Asia, Annual report 1993-1994. Khon Kaen Animal Nutrition Research Center, Department of Livestock Development, Ministry of Agriculture and Cooperative. pp. 124-131.

Steel, R. G. D. and J. H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach.McGraw-Hill, New York.

Suksri, A. 1993. Effects of Complete Chemical fertilizers on Growth and Seed yield of Eight-Soybean Cultivars Grown on

Yasothon Soil. Proceedings of 30th Anniversary, Department of Soil Science, Khon Kaen University, August 19-20, 1993, Khon Kaen, Thailand.

Thapra Meteorological Station 2003. Weather condition data, Muang District, Khon Kaen, Thailand.

Tournobeze, R. and H. Sinoquet. 1995. Light interception and partitioning in shrub/grass mixtures. Agric. Forest Meteor. 72:277-294.

Vandermeer, J. H. 1990. Intercropping. In: (Ed. C. R. Carroll, J. H. Vandermeer and P. M. Rosset), Agroecology.McGraw-Hill,New York, pp. 481-516.

Vandermeer, J. H. 1989. The Ecology of Intercropping. Cambridge University Press, Cambridge, UK.

Van Soest, P. J. and J. B. Robertson. 1991. Methods of dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583–3597.

Wanapat, M., 2003. Manipulation of cassava cultivation and utilization to improve protein to energy biomass for livestock feeding in the tropics. Asian-Aust. J. Anim. Sci. 16(3):463-472.

Wanapat, M. 1999. Feeding of Ruminants in the tropics based on Local Feed Resources. Khon Kaen Publ. Comp. Ltd., Khon Kaen, Thailand. p. 236.

Wanapat, M., O. Pimpa, A. Petlum and U. Boontao. 1997. Cassava hay: A new strategic feed for ruminants during the dry season. Livestock Research for Rural Development, 9(2): IRRD Home Page.

Wanapat, M., O. Pimpa, W. Siphuak, T. Puramongkon, A. Petlum, U. Boontao, C. Wachirapakorn and K. Sommart. 2000. Cassava hay: an important on-farm feed for ruminants. In: Proc. (Ed. J. D. Brooker), International Workshop on Tannins in Livestock and Human Nurition. ACIAR Proc. No. 92, pp. 71-74.

Wanapat, M., A. Polthanee and C. Wachirapakorn. 2002. Final Report on Livestock–Crop Systems Research Project-Thailand. The International Livestock Research Institute (ILRI) and Khon Kaen University, Thailand. p. 31.

Wanapat, M. and O. Poungchompu. 2001. Method for estimation of tannin by vanillin-HCl method (2001, a methode of Burns, 1971). Department of Animal Science, Khon Kean University, Khon Kaen 4002, Thailand.

Willey, R. W. 1979. Intercropping-its importance and research needs. I. Competition and yield advantages. Field Crop. Abstr. 32:1-10.

Willey, R. W. 1979. Intercropping-its importance and research needs: agronomy and research approaches. Field Crop Abstr. 32:78-85.