CASSAVA LEAF PRODUCTION RESEARCH IN THAILAND

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ABSTRACT

The unlignified upper part of the cassava plant is potentially a good source of protein for animal feed rations because of its high yield and nutritive value. Several experiments have revealed that the dry matter of these plant tops contains 20-32% crude protein, which consists of various essential amino acids in proportions close to those of soybean meal. Most research conducted in Thailand in the past focussed mainly on the utilization of cassava foliage to partially substitute for soybean meal in the feeding of different types of animals, such as cows, pigs, and poultry, in order to reduce the import of soybean meal. If only 10% (0.14 million tonnes) of soybean meal in animal feed is substituted by cassava leaf meal, the country would be able to save 900 million baht or 21 million U.S. dollars per year.

According to previous research conducted in Thailand, the annual yield of dry cassava foliage varied from 3.6 to 12.6 t/ha. Both yield and nutritive value depend to a large extent on both genetics and the environment. Hence, factors affecting yield and protein content of cassava foliage are presently being researched at different locations in order to determine the appropriate practices in cassava foliage production for each part of the country. A preliminary trial conducted in 2001/02 at Rayong Field Crops Research Center indicates that the total cassava dried foliage yields from 3 cuttings of 16 varieties and their protein contents were in the range of 4.0 to 7.7 t/ha and 19.7 to 26.8%, respectively, while root yields and starch contents at 12 months after planting ranged from 11.9 to 29.1 t/ha and 19.0 to 26.4%, respectively. A similar trial conducted at TTDI in Nakhon Ratchasima province resulted in total dry foliage yields of 2.6 to 8.2 t/ha with 11.5 to 34.3% protein, and 6.77 to 22.7 t/ha of fresh roots with 11.3 to 29.1% starch.

INTRODUCTION

Most research related to cassava leaves recently conducted in Thailand has focused on the utilization of cassava leaves or cassava hay to partially substitute for soybean meal in the feeding of dairy cows, cattle, pigs, and poultry, in order to reduce the importation of soybean meal. If only 10%, or 0.14 million tonnes, of soybean meal in animal feed is substituted by cassava leaf meal, the country would be able to save 900 million baht or 21 million U.S. dollars per year. Although the protein content of cassava leaves is not as high as that of soybean meal, it is not much different from those of some other sources of animal feed (**Tables 1, 2** and **3**). Therefore, it can be used to some extent for feeding different types of animals, mainly cattle, pigs and poultry. The role of cassava forage in animal feeding is presented by other authors. Research concerning factors affecting cassava leaf production conducted in the past until recently are presented in this paper.

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Table 1. Chemical composition of cassava leaves and hay compared with other protein sources in animal feed.

Parameter	Concentrate[1)]	Soybean meal[2)]	Dry pigeon pea leaves[2)]	Dry *Leucaena* leaves[2)]	Dry cassava leaves	Cassava hay
Dry matter	88.4	89.0	96.7	90.0	90.0[3)]-92.1[4)]	86.3[3)]
Composition (% of DM)						
Crude protein	17.7	49.0	19.8	22.4	20.6[4)]-24.7[3)]	23.6[1]-25.0[3)]
Crude fiber		8.2	23.2	20.0	17.3[3)]	
Neutral Detergent Fiber	48.7				29.6[3)]	44.3[1]-58.8[3)]
Acid Detergent Fiber	35.9				24.1[3)]	30.3[3]-32.0[4)]
Ether extract		0.9	7.3	3.9	5.9[3)]	
Nitrogen-free extract		32.7	43.7	43.9	44.2[3)]	
Ash	26.6	8.8	6.0	9.8	7.9[3)]	6.8[4]-17.5[3)]

Sources: *[1)] Metha Wanapat, 1999; [2)] Vimolruth Sukarinth, 1998; [3)] Metha Wanapat, 2002; [4)] Onanong Poungchompu et al., 2001.*

Table 2. Chemical composition of various cassava products, sorghum and alfalfa hay.

Parameter	Cassava products					Sorghum	Alfalfa hay
	Dry leaves	Dry forage	Fresh roots	Ensiled roots	Root meal		
Dry matter	89-90	91-92	35-40	40-45	90	88-89	89-90
Composition(% of DM)							
Crude protein	21	17-18	1-2	2-3	3.1	11	15
Crude fiber	20-24	17-18	1.5-2.0	3-4	3.4	2.0	29
Ether extract (fat)	6-7	5-6	0.2-0.5	1-2	1.3	2.8	1.7
Non-Nitrogen extract	27-35	39-44	30-36	30-32	80	70-71	34-35
Ash	8-10	9-10	1-2	2-3	2.1	1.7	9
Ca	1-1.4	1.75	0.05		0.12	0.04	1.4
P	0.25-0.28	0.32	0.07		0.16	0.29	0.20

Source: *Gomez et al., 1985.*

Table 3. Amino acid contents of various protein sources of animal feed (gm/16 gm N).

Amino acid	SM[1)]	CL[2)]	CH[3)]	AH[4)]	Amino acid	SM[1)]	CL[2)]	CH[3)]	AH[4)]
Alanine	4.4	5.7	6.3	na	Arginine	7.5	5.3	2.4	3.8
Asparagine	Na	Na	6.8	na	Aspartic acid	11.9	9.8	na	na
Cystine	1.6	1.4	0.3	0.2	Glutamine	19.0	12.3	9.6	na
Glycine	4.4	4.8	2.6	1.9	Histidine	2.8	2.3	1.5	1.2
Isoleucine	4.7	4.5	13.1	0.7	Leucine	7.1	8.2	2.9	1.1
Lysine	6.5	5.9	1.7	0.6	Methionine	1.6	1.9	0.6	0.2
Proline	5.6	Na	2.9	na	Phenylalanine	5.6	5.4	1.9	0.8
Serine	5.5	Na	2.8	na	Threonine	4.2	4.4	na	na
Tryptophan	Na	2.0	na	na	Tyrosine	4.7	4.0	1.8	0.4
Valine	5.1	5.6	2.4	0.7					

[1)] SM = soybean meal; [2)] CL = dry cassava leaves; [3)] CH = cassava hay; [4)] AH = alfafa hay.
Source: *Metha Wanapat, 2002.*

FACTORS AFFECTING CASSAVA FOLIAGE YIELD AND PROTEIN CONTENT

Cassava dried foliage yields reported from former research conducted in Thailand were in the range of 3.6 to 12.6 t/ha/year. Both yield and nutritive value depend considerably on genetics and the environment. Hence, factors affecting yield and protein content of cassava foliage, i.e. variety, plant age, fertilization, spacing, cutting frequency and cutting height, are being researched under different conditions in order to determine the most appropriate techniques for cassava foliage production for each part of the country.

1. Yield Potential and Varietal Difference in Yield and Protein Content

a. Cassava tops collected at root harvesting time

i) 12 months harvest

In May 1998, the foliage yields were determined of 119 clones planted in the Preliminary Yield Trial for root production at Rayong Field Crops Research Center. The varieties were planted in 5x10 m plots at a spacing of 1x1 m. Twenty four plants of each clone were harvested at 12 months after planting (MAP). Fresh foliage production of Rayong 1 and Rayong 90 were 4.31 and 2.91 t/ha while that of the most leafy one in the trial was 7.70 t/ha. In this case, most of the erect types had a thicker leaf canopy but fewer branches than the branchy types, which had a lower foliage production. Under Rayong's conditions the fresh foliage yield of an erect type is usually around 4 t/ha. The dry foliage weight is usually 25-30% of fresh weight, depending on varietal differences in dry matter content and the intensity of the sunlight during the drying process.

ii) 8 months harvest

Vicharn Vichukit (1979) harvested cassava leaves (without petioles) from an eight month old crop and indicated that fresh leaf and dried leaf production was 5.78 and 1.92 t/ha respectively. Sunee Kittivorawate (1996) also reported that the dry leaf yield from an eight month crop was as high as 2 t/ha.

Compared to the 12 month crop, cassava foliage production derived from the 8 month crop seemed to be not much different. In tropical countries, the season of harvest (wet or dry) has more effect on leaf yield than plant age, due to leaf shedding during the dry season.

Chareinsuk Rojanaridpiched (1988) reported that the protein content in the leaves of 13 cassava varieties harvested at 8 months varied from 21.6 to 26.7%. Rayong 1 and Rayong 3 had 22.2 and 22.6% crude protein in their leaves' dry matter, respectively.

b. Cassava tops collected at 3-4 month intervals

Metha Wanapat (1997) reported that the production of dry cassava hay could reach 12.6 t/ha/year when cassava was planted at narrow spacing and with the first harvest at 3 MAP, and thereafter every two months. Cassava tops were chopped and sun dried for 1-3 days before feeding to animals or keeping for later use. Protein production was 2.5 t/ha/year or about 20% of the dry weight.

2. Effect of Varieties on Leaf Production

Between May 2001 and May 2002, an experiment was conducted at Rayong Field Crops Research Center (RFCRC) in Rayong and at TTDI Research and Training Center in Nakhon Rachasima provinces to evaluate the potential of 16 cassava varieties for foliage production. Stakes were planted at 60x60 cm in RCB design with 4 replications in 3.6x3.6

m plots. Fertilizers were applied three times i.e. 500 kg/ha of 15-15-15 at planting, and 25 kg N/ha as urea after each of the first two cuttings. The plants were cut at 3 ½, 5 ½ and 12 months after planting at a height of 50-60 cm above the soil surface. Dry foliage yields and dry matter and protein contents varied among varieties and cuttings in both locations. Fast growth or higher leaf production seemed to result in lower protein contents (**Table 4**). Total production of dried leaves, protein and fresh roots are shown in **Tables 5** and **6**. The highest dry leaf yields at RFCRC and TTDI were 7.77 and 8.24 t/ha, respectively. The highest protein yields at the same two locations were 1.93 and 1.90 t/ha respectively. Root yield and starch content of some varieties were surprisingly high, even though they had had to regenerate leaves continuously.

Table 4. Dry leaf yields, dry matter contents and protein contents of three cuts of cassava leaves at RFCRC and TTDI, Thailand, in 2001/02.

	Cut 1 (3½ MAP)	Cut 2 (5½ MAP)	Cut 3 (12 MAP)
RFCRC			
Dry leaf yield (t/ha)	1.4-2.9	2.2-3.3	0.4-1.8
% D.M.	22-25	22-25	25-30
% protein (DM basis)	21-27	19-25	21-26
TTDI			
Dry leaf yield (t/ha)	0.7-2.5	0.9-2.4	1.1-4.0
% D.M.	-	20-24	26-32
% protein (DM basis)	25-37	24-31	11-19

Table 5. Total dry matter and protein yields of three cuts of cassava leaves[1)] as well as the fresh root yield and starch content at harvest at 12 MAP in Rayong Field Crops Research Center, Rayong, Thailand in 2001/02.

Variety/line	Leaf production (t DM/ha)				Crude protein yield (t/ha)				Root yield (t/ha)	Starch content (%)
	1st cut	2nd cut	3rd cut	Total	1st cut	2nd cut	3rd cut	Total		
1. Rayong 1	1.700	3.074	0.985	**5.759**	0.367	0.740	0.222	1.329	23.87	21.4
2. Rayong 5	2.151	2.617	0.794	**5.562**	0.592	0.648	0.184	1.424	29.12	25.6
3. Rayong 60	1.922	2.207	0.396	**4.525**	0.500	0.541	0.094	1.135	20.27	20.6
4. Rayong 90	1.172	2.349	0.522	**4.043**	0.290	0.514	0.125	0.929	16.49	25.1
5. Rayong 72	1.962	2.389	0.514	**4.865**	0.528	0.599	0.107	1.234	25.96	23.7
6. KU 50	1.985	2.234	0.908	**5.127**	0.532	0.563	0.179	1.274	21.31	25.5
7. Hanatee	1.580	2.459	0.452	**4.491**	0.358	0.549	0.103	1.010	11.98	19.8
8. OMR 39-42-54	1.396	2.965	0.718	**5.079**	0.373	0.778	0.152	1.303	16.19	23.3
9. CMR 40-84-154	1.725	3.101	1.337	**6.163**	0.377	0.591	0.328	1.296	15.54	20.1
10. CMR 41-42-3	1.741	3.394	1.205	**6.340**	0.477	0.891	0.301	1.669	21.79	26.4
11. CMR 41-60-24	2.987	3.219	1.562	**7.768**	0.670	0.852	0.402	1.924	23.78	25.1
12. CMR 41-61-59	2.025	3.010	0.797	**5.832**	0.457	0.691	0.187	1.335	23.79	19.0
13. CMR 41-61-118	2.118	2.832	1.126	**6.076**	0.501	0.627	0.283	1.411	21.14	22.0
14. CMR 41-111-129	1.979	3.128	0.926	**6.033**	0.485	0.773	0.222	1.480	22.39	23.7
15. CMR 41-114-125	1.704	3.369	1.631	**6.704**	0.446	0.737	0.349	1.532	25.00	25.7
16. CMR 41-23-41	1.373	3.035	1.791	**6.199**	0.365	0.664	0.357	1.386	20.61	25.2
Average	1.845	2.836	0.979	**5.660**	0.457	0.672	0.225	1.354	21.20	23.3

[1)]Young stems, leaves and petioles cut at 3½ , 5½ and 12 months after planting.

Table 6. Total dry matter and protein yields of three cuts of cassava leaves[1)] as well as the fresh root yield and starch content at harvest at 12 MAP in the Thai Tapioca Develop. Institute (TTDI) in Huay Bong, Nakhon Ratchasima, Thailand in 2001/02.

Variety/line	Leaf production (t DM/ha)				Crude protein yield (t/ha)				Root yield (t/ha)	Starch content (%)
	1st cut	2nd cut	3rd cut	Total	1st cut	2nd cut	3rd cut	Total		
1. Rayong 1	0.721	1.507	2.291	**4.519**	0.237	0.424	0.444	1.105	9.63[2)]	15.0[2)]
2. Rayong 5	1.660	1.478	3.443	**6.581**	0.487	0.404	0.643	1.534	22.74	27.4
3. Rayong 60	0.626	0.924	1.101	**2.651**	0.232	0.292	0.208	0.732	6.77[2)]	12.8[2)]
4. Rayong 90	1.010	1.075	1.428	**3.513**	0.293	0.289	0.262	0.844	12.50	23.4
5. Rayong 72	1.661	1.527	2.350	**5.538**	0.480	0.462	0.417	1.359	21.35	24.8
6. KU 50	1.617	1.269	2.431	**5.317**	0.359	0.315	0.389	1.063	21.27	26.2
7. Hanatee	1.350	1.748	1.702	**4.800**	0.380	0.505	0.341	1.226	6.77[2)]	11.3[2)]
8. OMR 39-42-54	1.648	2.117	3.330	**7.095**	0.466	0.509	0.610	1.585	16.14	25.4
9. CMR 40-84-154	1.556	2.099	2.766	**6.421**	0.465	0.611	0.387	1.463	12.15[2)]	16.4[2)]
10. CMR 41-42-3	1.857	1.762	3.641	**7.260**	0.466	0.525	0.637	1.628	19.27	26.0
11. CMR 41-60-24	2.380	1.858	3.369	**7.607**	0.628	0.564	0.610	1.802	14.76	29.0
12. CMR 41-61-59	2.560	1.318	3.693	**7.571**	0.701	0.364	0.427	1.492	19.88	20.7
13. CMR 41-61-118	1.748	2.414	4.011	**8.173**	0.498	0.641	0.763	1.902	11.55[2)]	16.9[2)]
14. CMR 41-111-129	2.199	1.743	3.037	**6.979**	0.588	0.465	0.452	1.505	18.31	22.2
15. CMR 41-114-125	2.408	1.982	3.939	**8.239**	0.635	0.494	0.483	1.612	21.35	29.1
16. CMR 41-23-41	1.671	2.285	3.621	**7.577**	0.469	0.626	0.675	1.770	13.45	24.1
Average	1.667	1.694	2.884	**6.246**	0.461	0.468	0.484	1.414	15.49	21.9

[1)] Young stems, leaves and petioles cut at 3½, 5½ and 12 months after planting

[2)] Low yield and low starch content due to very poor growth in one of the four replications, prodably due to Zn deficiency.

In May 2002, similar trials were planted in Rayong, Nakorn Rachasima, Khon Kaen and Songkhla provinces to evaluate the potential of 25 cassava varieties for foliage production. In this case, stakes were planted at a spacing of 30x30 cm corresponding to a population of 111,111 plants/ha, which is four times those of the previous trials; plants were fertilized with 500 kg/ha of 15-15-15 fertilizer at planting and 25 kg N/ha after each cut. The first leaf harvest was at 2.5-3 months after planting by cutting the top parts at 20 cm above the soil surface. Yields varied among varieties and locations (**Table 7**). The highest fresh and dry foliage production at the first cut at Rayong was 15.56 and 3.17 t/ha, respectively. Some of the tested varieties produced 20 tonnes of fresh leaves per ha in some replications. The dry matter contents (determined after 5 days in the oven at 50ºC) was 17.5-22.6% of the fresh weight. The protein content has not been analyzed at this moment. Leaf production from the first cut at Songkhla and Khon Kaen are quite high compared to those at Rayong.

3. Fertilizer Application and Ridging

Onanong Poungchompu *et al*. (2001) conducted a trial to determine the effect of cow manure application and ridging on cassava leaf production. KU 50 was planted at a spacing of 50x30 cm in 4x8 m plots, and was first cut at 10-15 cm above the ground at 3 MAP, and every two months thereafter. It was concluded that ridging had no effect, while manure application (1,250 kg/ha) tended to increase cassava foliage yield but not the

protein content (**Table 8** and **9**) . The total dry foliage yield reached 4.4 t/ha with ridging and manure application.

Table 7. Range of fresh leaf yields, dry matter contents and dry leaf yields of the first cut of 25 cassava varieties in leaf production trials at Rayong, Khon Kaen and Songkla, Thailand in 2002/03.

	Rayong	Khon Kaen	Songkla
Fresh leaves[1)] (t/ha)	5-15	10-23	13-24
D.M. (%)	17-22	16-18	20-23
Dry leaves (t/ha)	1.4-3.1	1.8-4.2	2.8-5.4

[1)] Includes upper green stem and petioles

Table 8. Effect of ridging and manure application on the foliage yield of cassava (KU 50) cut at 3, 5 and 12 MAP at Khon Kaen in 2000/01.

	With ridging		Without ridging	
	without manure	with manure	without manure	with manure
Fresh yield (t/ha)				
Cutting: 1st	3.71	3.99	3.79	3.46
2nd	3.06	3.12	3.12	3.27
3rd	6.02	7.66	5.71	7.77
Total	**12.79**	**14.77**	**12.62**	**14.50**
Dry yield (t/ha) and D.M. (%)				
Cutting: 1st	1.12 (30)	1.20 (30)	1.14 (30)	1.04 (30)
2nd	0.95 (31)	0.94 (30)	0.97 (31)	1.02 (31)
3rd	1.80 (29)	2.27 (29)	1.54 (27)	2.17 (27)
Total	**3.87 (30)**	**4.41 (30)**	**3.66 (29)**	**4.23 (29)**

***Source**: Onanong Poungchompu et al., 2001.*

Table 9. Effect of ridging and manure application on the chemical composition of cassava dry Foliage, cut at 3, 5 and 12 MAP at Khon Kaen in 2000/01.

	With ridging		Without ridging	
	without manure	with manure	without manure	with manure
Dry matter content (%)	92.0	91.9	92.1	91.8
Composition (% of DM)				
Ash	7.1	6.8	7.1	6.9
Crude protein	22.0	20.6	20.9	20.6
NDF	58.1	58.8	58.5	57.6
ADF	31.7	32.0	31.0	31.0
Condensed tannins (mg/kg)	40.0	38.0	38.0	42.0

***Source**: Onanong Poungchompu et al., 2001.*

In 2002, a trial was conducted at Rayong and Khon Kaen Field Crops Research Centers to determine the fertilizer requirements for cassava leaf production by planting Rayong 5 and Rayong 72 in plots of 2.1x3 m with a plant spacing of 30x30 cm. Twelve combinations of four levels each of N, P and K fertilizers were applied. The crop was first cut at 2.5 months after planting, and thereafter at 2 months intervals.

The data from the first cutting indicates that the two varieties responded differently to fertilizer application and the response varied between locations according to the climate and the fertility of the soil (**Figure 1**).

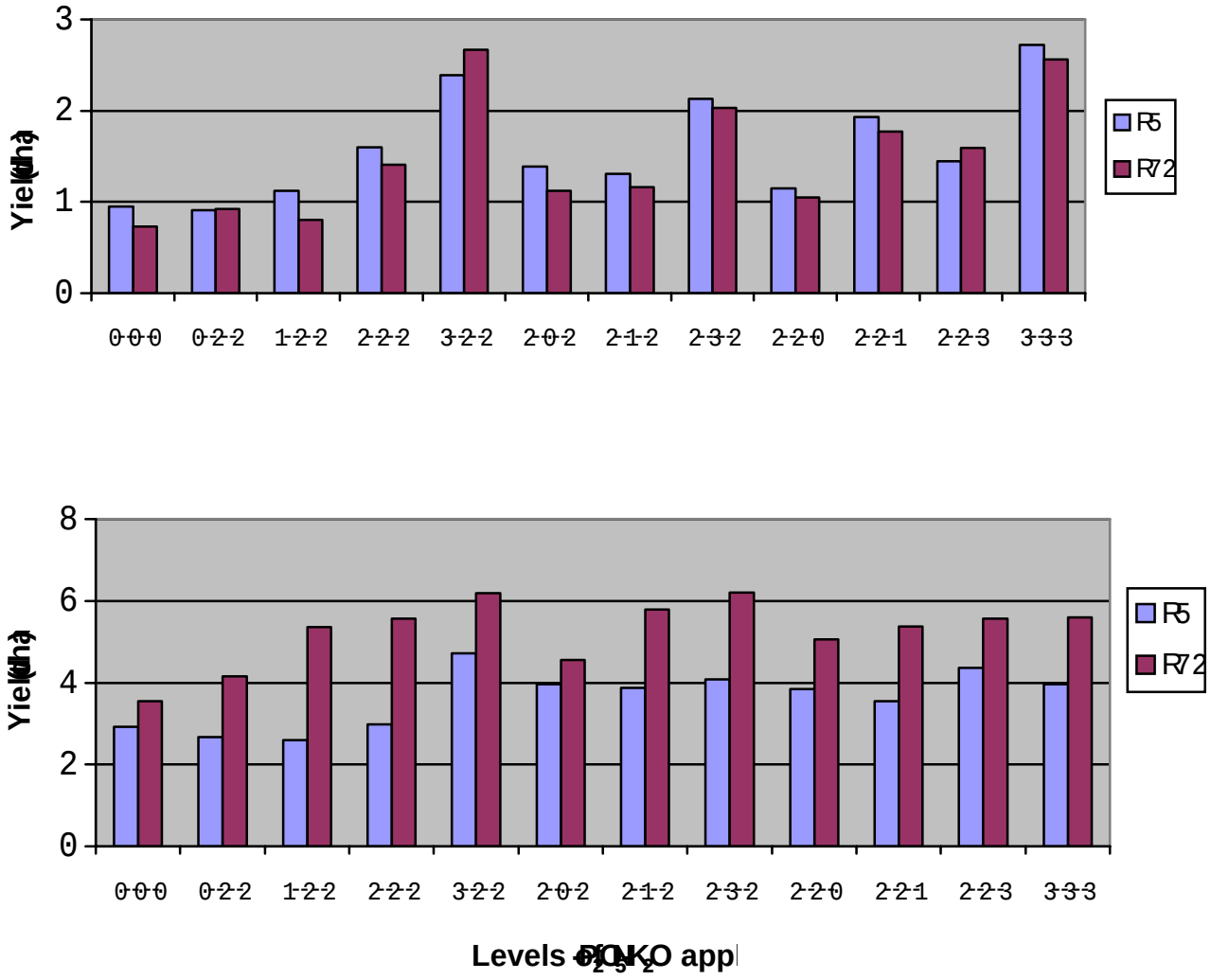

Figure 1. The effect of various combinations of N, P and K on the dry foliage yield of two cassava varieties planted at Rayong (top) and Khon Kaen (bottom) Field Crops Research Centers in Thailand in 2002. Data correspond to the first cut at 2½ MAP.

4. Plant Spacing and Cutting Height and Frequency

Somsak Thongsri, Kumpol Narintaraporn and Utai Cenpukdee conducted several experiments to determine the effect of plant spacing and cutting frequency on fresh leaf yield and root yield of Rayong 1 (RFCRC Annual Reports for 1977, 1978 and 1979). The following conclusions could be drawn ;

1) spacings had no significant effect on leaf yield, but did have an effect on root yield (**Table 10**)
2) leaf yield increased but root yield decreased as cutting frequency increased (**Table 11**)
3) plant spacing and cutting frequency had no significant interaction effect on leaf yield.

Table 10. Effect of plant spacings on leaf and root yields of Rayong 1 at Rayong Field Crops Research Center during 1977-1979.

Spacing	Fresh leaf yield (t/ha)				Root yield (t/ha)			
(cm)	1977	1978	1979	**Av.**	1977	1978	1979	**Av.**
40x40	7.06	7.50	7.19	**7.25**	7.75	21.06	12.94	**13.92**
40x50	8.25	8.12	7.87	**8.08**	9.81	25.12	15.00	**16.64**
50x50	6.37	8.06	6.94	**7.12**	9.69	23.00	14.62	**15.77**
80x40	7.81	10.37	8.37	**8.85**	12.37	28.37	18.12	**19.62**
100x50	6.87	8.19	7.31	**7.45**	12.25	27.75	18.69	**16.56**
100x100	6.50	7.31	7.00	**6.94**	14.50	31.50	21.62	**22.54**

Source: *Rayong Field Crops Research Center, Annual Reports, 1977, 1978, 1979.*

Table 11. Effect of cutting intervals on leaf and root yield of Rayong 1 at Rayong Field Crops Research Center during 1977-1979.

Cutting frequency	Fresh leaf yield (t/ha)				Root yield (t/ha)				(%)
	1977	1978	1979	**Av.**	1977	1978	1979	**Av.**	starch
1x (at harvest)	5.31	4.00	4.75	**4.69**	13.25	31.31	19.81	**21.46**	17.5
2x (at 6 and 12 MAP)	5.19	4.19	4.81	**4.73**	12.19	29.00	18.50	**19.90**	17.3
3x (every 4 months)	7.56	11.44	8.50	**9.17**	11.06	23.12	16.06	**16.75**	18.6
6x (every 2 months	10.56	13.50	11.62	**11.89**	7.62	13.50	12.94	**11.35**	17.4

Source: *Rayong Field Crops Research Center, Annual Reports, 1977, 1978, 1979.*

The effect of cutting frequency and cutting height are again being investigated at Rayong and Khon Kaen in 2002/03. In this trial, Rayong 5 is planted with a spacing of 30x30 cm and first cut at 2.5 months after planting at different cutting height, i.e. 15, 20 and 25 cm above the soil surface. Cutting frequency of the next cuttings are every 1.5, 2 , 2.5, and 3 months. Effect of cutting height on dry leaf yield from the first cutting at Rayong and Khon Kaen Center are shown in **Table 12**, but other results will be reported when the trial has finished.

Table 12. Effect of cutting height on the dry leaf yield at first cutting (2½ MAP) of Rayong 5 at Rayong and Khon Kaen Field Crops Research Centers, Thailand in 2002/03.

Cutting height (cm)	Dry leaf yield (t/ha)	
	Rayong	Khon Kaen
15	2.65	4.20
20	2.62	3.59
25	2.38	3.57

CONCLUSIONS

Cassava leaf production research in Thailand was initiated 30 years ago but the results were not utilized due to lack of demand for cassava leaves in the country. It is now national policy to try to utilize all parts of many crops to increase the economic returns to farmers. Current research to optimize cassava leaf production is in response to the potential utilization of cassava leaves for animal feeding, and cassava stems for paper making. Definite results on the best varieties, the fertilizer requirements and the optimum plant spacing, cutting height and frequency should be available during the next four years. CIAT has played an important role in this project by initiating strategic research on cassava leaf production in some parts of the country, which can later be applied to other areas.

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