MARDI Res. J. 20(1) 1992: 1–14

Selection for early cassava clones

(Pemilihan klon ubi kayu cepat matang)

S. L. Tan*

Key words: cassava, early harvestability, clonal selection, rate of returns

Abstrak

Potensi untuk memilih klon-klon ubi kayu yang cepat matang (dapat dipungut hasil selepas 6 bulan berbanding dengan 12 bulan) didapati baik. Usaha-usaha ke arah ini telah menghasilkan klon CM 3906–31 yang dapat megeluarkan hasil sebanyak 36 t/ha pada 6 bulan di tanah gambut dan 43 t/ha pada 6 bulan di tanah mineral di kawasan-kawasan yang tidak mengalami sesuatu musim kemarau. Jika kemarau selama 2–4 bulan berlaku semasa musim menanam, hasil ubi pada 6 bulan boleh terjejas. Masa pemungutan klon CM 3906–31 juga boleh dilambatkan kerana klon ini mengeluarkan hasil ubi yang sama tinggi atau lebih tinggi daripada hasil Perintis selepas 12 bulan. Sungguhpun mempunyai indeks pemungutan hasil yang tinggi (iaitu cekap menyimpan asimilat untuk hasil berekonomi), CM 3906–31 mempunyai kandungan kanji yang rendah dalam ubi.

Penanaman klon-klon cepat matang menunjukkan kelebihan ekonomi berbanding dengan klon-klon 12-bulan, terutama pada aras hasil yang boleh diperoleh daripada CM 3906–31. Pada tempoh masa penanaman 8 tahun, Perintis dapat ditanam tujuh kali manakala CM 3906–31 dapat ditanam 12 kali. Pengiraan kos dan pulangan menunjukkan bahawa CM 3906–31 akan mendatangkan keuntungan yang melebihi pulangan daripada Perintis sebanyak $1 182–$2 126/ha setahun pada harga ubi basah $83–$116/t.

Abstract

The potential for selecting early clones of cassava, harvestable at 6 months instead of the traditional 12, is good. Efforts in this direction have resulted in the selection of a clone CM 3906–31 capable of yielding 36 t/ha at 6 months on drained peat and 43 t/ha at 6 months on mineral soils in areas which do not experience a distinct dry season. Where a dry season of 2–4 months occur within the cropping season, 6-month root yields were severely depressed. CM 3906–31 also showed flexibility in harvesting time, being as high yielding or higher yielding than Perintis at the 12-month harvests. Although having a high harvest index (efficient in partitioning assimilates towards economic yield), CM 3906–31 tends to have a low starch content in the roots.

Planting early clones shows an economic advantage over 12-month clones, particularly at the levels of yield which may be expected of CM 3906–31. Over an 8-year cropping period which allows for seven crops of Perintis and 12 of CM 3906–31, theoretical calculations indicate a profit advantage ranging from $1 182/ha to $2 126/ha per year from CM 3906–31 at market prices for fresh roots varying from $83/t to $116/t.

*Division of Horticulture, MARDI Headquarters, P.O. Box 12301, 50774 Kuala Lumpur, Malaysia
Author's full name: Tan Swee Lian

Introduction

Cassava (*Manihot esculenta* Crantz) has long been a traditional backyard food crop in Malaysia as well as a commercial starch-producing crop grown on varying scales ranging from a few plants to 500 ha. Although a shortlived perennial by botanical description (Cobley 1963; Purseglove 1974), it is an annual crop by agronomic practice. It is a long-term annual requiring on the average 12 months' growth to harvest, and on this very score has not been as popular as shorter term annuals such as maize and groundnut which promise faster returns.

This last-mentioned scenario is apt to change with the advent of early cassava clones. Earliness in cassava may be defined as early root bulking leading to early high yields, in this case after 6 months of growth. Earliness has not much to do with physiological or sexual maturity of the crop since the economic part of the plant is non-sexual in nature and is in effect a storage organ, the modified root. So, instead of waiting for 12 months to harvest a cassava crop, it will be possible to expect an economic yield after 6 months, reducing the production time by half.

Work on the selection of early cassava clones began in MARDI in 1982 in an attempt to popularize the cultivation of cassava as a commercial large-scale crop. Malaysia is in short supply of starch resources, either for industrial use (food, sweetener, textiles, paper, etc.) or for livestock feed (Tan et al. 1989). Cassava is the easiest starch-producing crop to grow in the humid tropics, being adaptable to a wide range of agro-climatic and edaphic conditions and having relatively few serious pests and diseases. By contrast, other starch-producing crops are less adaptable: maize has problems with yield stability, pests and diseases, sweet potato is often plagued by weevil attacks, while white potato and wheat are unsuited to the tropical environment.

Materials and methods

Selection for early cassava clones entailed the incorporation of an additional harvest into the selection scheme for new cassava seedling clones at the stage of advanced yield trials, which follow preliminary yield trials, single-row trials and seedling evaluation (Tan 1989b). The use of earliness as a selection criterion could not be introduced in the initial stages of selection as there was insufficient planting materials then. This scheme enables both genotypes which produce early high yields (after 6 months) as well as those which are relatively slower in root bulking (high yields at 12 months) to be differentiated.

A seed lot introduced from CIAT (Centro Internacional de Agricultura Tropical) in 1982 went through the above selection scheme. By 1987, 12 clones were shortlisted as having the early characteristic. These were tested in four yield trials from 1989 to 1990, two seasons at the MARDI Integrated Peat Research Station in Pontian, and one season each at MARDI research stations Bukit Tangga and Serdang, respectively. Both Pontian and Serdang are in Agro-ecological Zone 3 (AEZ 3) with no distinct dry period, while Bukit Tangga is in AEZ 1, having a dry period lasting from 3–4 months per year (Nieuwolt et al. n.d. [1982]).

A randomized complete block design was adopted, with four replications per trial. Although each plot provided for two harvests, the design was not strictly a split-plot because the harvest areas were fixed and not randomized. At Pontian, C 5 [a 9-month clone hitherto recommended as early (Chan et al. 1983)] and Perintis [a newly released high-yielding clone (Anon. 1988b)] were used as check clones. At Bukit Tangga and Serdang, the same two as well as Black Twig, the widely cultivated commercial variety, were used as checks.

The usual agronomic practices recommended for peat and mineral soils (Tan 1989a) were adopted accordingly, and the planting distance of 0.9 m x 0.9 m was used. Plot size measured 6.3 m x 11.7 m. This provided for the harvest of 25 central plants at 6 and 12 months, leaving out a border row all round.

At each of the two harvests, data were collected on fresh root yield, harvest index (ratio of root weight over total plant weight), starch content of the roots [estimated by measurements on the specific gravity (Noor Auni and Tan 1980)] and starch yield (calculated by the relationship of fresh root yield x starch content).

Combined analyses of the data were also carried out in two ways: over two seasons at Pontian and over three locations. As clones were considered fixed effects while seasons were random, expectations of mean squares (EMS) for a combined analysis of variance over two seasons at Pontian are as in *Table 1.*

The mean squares for clones (M_1) are therefore tested against the mean squares for clone x season (M_3). The test for seasons uses a composite of M_2 + M_5 divided by M_3 + M_4. For clone x season (M_3) and replicate within season (M_4), the error term M_5 is used.

In the combined analysis over locations (using data from only the first season trial at Pontian together with data from the Bukit Tangga and Serdang trials), clones and locations were considered as fixed effects with the expectations of mean squares given in *Table 2*. As Black Twig did not feature in the Pontian trial, data from this clone were eliminated from the combined analyses of variance.

In this case, testing for clones (M_1) uses the mean squares for clone x location (M_3), while for locations the composite M_2 + M_5 is tested with M_3 + M_4. Clone x location (M_3) and replicate within location (M_4) are both tested using the error term M_5.

Results and discussion

Performance at Pontian over two seasons

For the 6-month harvest data, although clones were not significantly different for root and starch yields *(Table 3)*, the LSD test still detected a significant difference in the yields of CM 3906–31 compared with the yields of the check clones *(Table 4)*. CM 3906–31 stands out as a promising early clone, giving a mean fresh root yield of 36.2

Table 1. Expected mean squares (EMS) for the different sources of variance in a combined analysis of variance over two seasons at Pontian

Source	df	EMS	Mean square
Clones (C)	13	$\sigma^2_e + 4\,\sigma^2_{cs} + 8\,\Sigma\,(C_j - \bar{C})^2/13$	M_1
Seasons (S)	1	$\sigma^2_e + 14\,\sigma^2_{r(s)} + 4\,\sigma^2_{cs} + 56\,\sigma^2_s$	M_2
C x S	13	$\sigma^2_e + 4\,\sigma^2_{cs}$	M_3
Replicate within S	6	$\sigma^2_e + 14\,\sigma^2_{r(s)}$	M_4
Error	78	σ^2_e	M_5

Table 2. Expected mean squares (EMS) for the different sources of variance in a combined analysis of variance over the three locations viz. Pontian (1st season), Bukit Tangga and Serdang

Source	df	EMS	Mean square
Clones (C)	13	$\sigma^2_e + 4\,\sigma^2_{cl} + 12\,\Sigma\,(C_j - \bar{C})^2/13$	M_1
Locations (L)	2	$\sigma^2_e + 14\,\sigma^2_{r(l)} + 4\,\sigma^2_{cl} + 56\,\Sigma\,(L_i - \bar{L})^2/2$	M_2
C x L	26	$\sigma^2_e + 4\,\sigma^2_{cl}$	M_3
Replicate within L	9	$\sigma^2_e + 14\,\sigma^2_{r(l)}$	M_4
Error	117	σ^2_e	M_5

Table 3. Mean squares for variance components of four traits at 6 months over two seasons of testing at MARDI Integrated Peat Research Station Pontian

		Mean squares			
Source	df	Root yield	Harvest index	Starch content	Starch yield
Clones (C)	13	146.674	0.0545**	5.977	8.232
Seasons (S)	1	75.247	0.0099	111.196**	25.393**
C x S	13	80.194**	0.0121**	2.694	4.287**
Replicate[S]	6	7.776	0.0261**	5.229**	1.353
Error	78	13.651	0.0040	1.637	0.881

**Significant at probability level of $p = 0.01$

Table 4. Effect of clone and season on harvest data at 6 months at MARDI Integrated Peat Research Station Pontian

Factor	Root yield (t/ha)	Harvest index	Starch content (%)	Starch yield (t/ha)
Clone				
CM 3371–22	29.1	0.59	24.2	7.0
CM 3380–10	30.6	0.61	23.2	7.2
CM 3388–15	28.6	0.57	22.6	6.4
CM 2527–7	23.6	0.43	22.8	5.4
CM 2975–21	24.5	0.46	22.5	5.5
CM 3299–26	27.7	0.58	23.8	6.6
CM 3906–31	36.2	0.61	22.0	8.1
CM 3707–31	26.3	0.50	22.6	6.0
CM 3906–13	28.1	0.55	22.8	6.5
CM 3898–6	26.7	0.52	23.1	6.2
CM 3855–37	27.7	0.57	23.7	6.6
CM 3303–21	18.7	0.42	23.0	4.3
C 5	20.4	0.37	21.9	4.5
Perintis	29.4	0.63	20.8	6.0
Mean	27.0	0.53	22.8	6.2
C.V.(%)	13.7	12.0	5.6	15.2
$LSD_{0.05}$	3.7	0.06	1.3	0.9
Season				
First	27.8	0.54	23.8	6.6
Second	26.2	0.52	21.8	5.7
$LSD_{0.05}$	1.4	0.02	0.5	0.4

t/ha at 6 months *(Plate 1)* compared with only 20.4 t/ha from C 5 and 29.4 t/ha from Perintis. Starch yield was also superior at 8.1 t/ha at 6 months.

It should be mentioned that the first season's yield of CM 3906–31 was even more spectacular at 41.7 t/ha at 6 months (data not presented). In the second season, Perintis showed some promise as an early clone with a root yield of 35.7 t/ha at 6 months.

Harvest index of CM 3906–31 was as high as in Perintis and significantly better than that of C 5. A high harvest index implies efficiency in producing economic yield. Starch content of this new clone was not significantly different from the contents of the check clones.

Plate 1. Yield and plant type of CM 3906–31 at 6 months from cultivation on drained peat (MARDI Integrated Peat Research Station Pontian)

Seasons produced significant differences in starch content and starch yield *(Table 4)*, being higher in the first season. The clone x season interaction had significant effects on root and starch yields as well as for harvest index, but not for starch content *(Table 3)*.

Analysis of variance on data at 12 months show clones to be significant for root yield, starch content and harvest index *(Table 5)*. By 12 months, Perintis had overtaken CM 3906–31 as the highest yielding clone, giving a mean root yield of 43.3 t/ha per year *(Table 6)*. Nevertheless, CM 3906–31 which featured second highest had a non-significantly different yield of 42.8 t/ha per year. The starch yields of Perintis and CM 3906–31 were also non-significantly different at this stage, but harvest index of Perintis was significantly higher. Starch content of CM 3906–31 at 12 months was similar to that of Perintis but significantly lower than that of C 5.

Seasons were significant in producing differences in root yield, harvest index, starch content and starch yield, again higher in the first season *(Table 6)*. As at 6 months, except in the case of starch content, the clone x season interaction was significant for the other three traits.

Performance at Bukit Tangga

Six-month root yields at Bukit Tangga were far below expectations *(Table 7)*, mainly because the dry season set in just 2 months after crop establishment and the 6-month crop was harvested soon after the onset of the rains. Perintis had the highest yield of 15.3 t/ha at 6 months while CM 3906–31 produced a non-significantly different yield of 14.1 t/ha at 6 months. Differences in the low starch yields of the various clones were too small to detect statistically.

Nevertheless, harvest indices in CM 3906–31 and in Perintis were high, indicating that under less favourable conditions of growth there was still higher efficiency in partitioning assimilates towards

Table 5. Mean squares for variance components of four traits at 12 months over two seasons of testing at MARDI Integrated Peat Research Station Pontian

Source	df	Mean squares			
		Root yield	Harvest index	Starch content	Starch yield
Clones (C)	13	179.298*	0.0411**	17.013**	4.722
Seasons (S)	1	2 329.613**	0.0405**	115.480**	212.067**
C x S	13	67.777*	0.0061*	1.853	3.523*
Replicate[S]	6	65.487	0.0057	5.146	6.840**
Error	78	27.309	0.0030	2.410	1.606

*Significant at probability level of $p = 0.05$
**Significant at probability level of $p = 0.01$

Table 6. Effect of clone and season on harvest data at 12 months at MARDI Integrated Peat Research Station Pontian

Factor	Root yield (t/ha)	Harvest index	Starch content (%)	Starch yield (t/ha)
Clone				
CM 3371–22	33.2	0.62	21.2	7.1
CM 3380–10	35.4	0.65	21.2	7.5
CM 3388–15	38.8	0.66	20.7	8.1
CM 2527–7	36.7	0.55	23.0	8.5
CM 2975–21	34.7	0.61	22.8	8.0
CM 3299–26	34.6	0.62	23.6	8.2
CM 3906–31	42.8	0.66	19.3	8.4
CM 3707–31	30.7	0.52	21.6	6.6
CM 3906–13	32.7	0.58	24.2	8.0
CM 3898–6	34.4	0.61	22.1	7.7
CM 3855–37	30.3	0.62	22.8	7.0
CM 3303–21	28.6	0.56	22.7	6.5
C 5	27.6	0.44	22.6	6.2
Perintis	43.3	0.73	19.4	8.4
Mean	34.6	0.60	21.9	7.6
C.V.(%)	15.1	9.1	7.1	16.7
$LSD_{0.05}$	5.2	0.05	1.5	1.3
Season				
First	39.1	0.62	23.0	9.0
Second	30.0	0.58	20.9	6.2
$LSD_{0.05}$	2.0	0.02	0.6	0.5

the economic part of the plant than in C 5 or Black Twig. Starch content of CM 3906–31 (at 17.2%) was similar to that of Perintis (18.0%) but lower than those of C 5 (19.6%) and Black Twig (21.2%).

However, at 12 months *(Table 8)*, root yields had improved considerably [proving yet again that even areas in AEZ 1 can produce high cassava yields if timing of planting provides sufficient time for the crop to recover from the effects of the 3 to 4-month drought (Tan 1989a)]. Perintis and CM 3906-31 gave the highest fresh root yields (> 43 t/ha per year). Equally high-yielding were CM 3898–6 and CM 3299–26. These two clones had starch yields second only to Perintis.

At 12 months, only CM 3906–31 retained its high harvest index, whereas in Perintis harvest index was not significantly different from that of C 5. Starch content of CM 3906-31, however, had become significantly lower than the check clones.

Performance at Serdang

Fresh root yield was again outstandingly higher in CM 3906–31 at 6 months (43.0 t/ha at 6 months) than any of the other clones, with C 5, Perintis and Black Twig at 21.7, 26.5 and 18.2 t/ha at 6 months respectively *(Table 7)*. Hence, CM 3906–31 produces early high root yields on both drained peat and mineral soils. Starch yield was also highest in this clone.

Harvest index in CM 3906–31 was significantly higher than any other clone, including Perintis. Unfortunately, starch content of this new clone was inferior to those of the check clones.

At 12 months, the highest yielder was still CM 3906–31 at a fresh root production of 59.3 t/ha per year *(Table 8)*. Starch yields on the other hand were not significantly

Table 7. Mean harvest data on five top cassava clones at 6 months against the checks C 5, Perintis and Black Twig at MARDI research stations at Bukit Tangga and Serdang

Clone	Root yield (t/ha)	Harvest index	Starch content (%)	Starch yield (t/ha)
Bukit Tangga				
CM 2975–21	14.2	0.59	19.6	2.8
CM 3906–31	14.1	0.69	17.2	2.4
CM 3906–13	12.5	0.59	19.0	2.4
CM 3380–10	12.0	0.52	21.2	2.6
CM 3898–6	9.7	0.45	20.4	2.0
C 5	8.3	0.52	19.6	1.6
Perintis	15.3	0.62	18.0	2.7
Black Twig	12.8	0.44	21.2	2.8
Mean of 15 clones	10.6	0.54	19.9	2.1
C.V. (%)	43.2	13.4	4.6	44.9
$LSD_{0.05}$	6.5	0.10	1.3	ns
Serdang				
CM 3906–31	43.0	0.67	20.5	8.8
CM 3707–31	29.1	0.49	23.8	6.9
CM 2527–7	26.9	0.45	24.3	6.5
CM 3371–22	25.2	0.50	24.2	6.1
CM 3855-37	24.2	0.50	25.8	6.2
C 5	21.7	0.38	22.1	4.8
Perintis	26.5	0.54	21.8	5.7
Black Twig	18.2	0.36	24.5	4.5
Mean of 15 clones	25.5	0.49	23.3	5.9
C.V. (%)	15.1	10.2	3.4	15.3
$LSD_{0.05}$	5.5	0.07	1.1	1.3

different for CM 3906–31, Perintis and Black Twig, mainly because of the inferior starch content of the first. Harvest indices significantly higher than in C 5 and Black Twig were recorded by CM 3906–31 and Perintis.

Performance over three locations

Clones and clone x location interaction were significant for the four traits studied at 6 months *(Table 9)*. Locations were not significant for harvest index. Over the three locations, CM 3906–31 outyielded C 5 and Perintis as well as the other clones in both root and starch yields *(Table 10)*. Root and starch yields as well as starch content were higher at Pontian and at Serdang than at Bukit Tangga *(Table 10)*.

At 12 months, locations were significant for the four traits, whereas clones were not significant for starch yield while clone x location was not significant for fresh root yield *(Table 11)*. Here again, CM 3906–31 had a significantly higher mean root yield compared with the other 13 clones, including the checks *(Table 12)*. The LSD test was also able to detect that five clones, these being CM 3898-6, CM 3299–26, CM 2527–7, Perintis and CM 3906–13, had starch yields similar to that of CM 3906–31. Again, Pontian and Serdang showed higher mean root and starch yields than Bukit Tangga *(Table 12)*.

Variance components and their implications in breeding

Generally, whether the cassava crop is harvested at 6 or at 12 months, starch yield is a character which is significantly influenced by season and location, as well as

Table 8. Mean harvest data on five top cassava clones at 12 months against the checks C 5, Perintis and Black Twig at MARDI research stations at Bukit Tangga and Serdang

Clone	Root yield (t/ha)	Harvest index	Starch content (%)	Starch yield (t/ha)
Bukit Tangga				
CM 3906–31	43.3	0.63	19.0	8.2
CM 3898–6	42.9	0.59	23.2	9.8
CM 3299–26	41.6	0.56	24.5	10.2
CM 3707–31	38.1	0.49	23.5	8.9
CM 3855–37	36.4	0.59	25.6	9.3
C 5	32.8	0.51	23.5	7.7
Perintis	49.4	0.52	20.9	10.3
Black Twig	26.0	0.39	24.2	6.3
Mean of 15 clones	36.2	0.53	23.0	8.3
C.V. (%)	23.7	13.5	4.9	24.0
$LSD_{0.05}$	12.3	0.10	1.6	2.8
Serdang				
CM 3906–31	59.3	0.75	21.6	12.9
CM 2975–21	46.2	0.59	27.7	12.8
CM 3898–6	45.9	0.61	27.7	12.7
CM 2527–7	44.6	0.57	28.0	12.5
CM 3388–15	43.4	0.70	26.2	11.4
C 5	32.9	0.47	26.5	8.7
Perintis	41.2	0.71	25.0	10.2
Black Twig	35.5	0.48	29.2	10.4
Mean of 15 clones	41.1	0.60	26.9	11.0
C.V.(%)	14.5	9.5	3.0	15.3
$LSD_{0.05}$	8.5	0.08	1.2	2.4

Table 9. Mean squares for variance components of four traits at 6 months from testing over three locations (MARDI Integrated Peat Reseach Station Pontian, MARDI research stations at Bukit Tangga and Serdang)

Source	df	Mean squares			
		Root yield	Harvest index	Starch content	Starch yield
Clones (C)	13	208.315**	0.0501**	11.604**	9.064**
Locations (L)	2	4674.521**	0.0387	262.962**	322.662**
C x L	26	42.123*	0.0074*	2.417**	2.416**
Replicate[L]	9	18.537	0.0168**	3.303**	1.218
Error	117	23.239	0.0037	0.878	1.144

*Significant at probability level of $p = 0.05$
**Significant at probability level of $p = 0.01$

clone x season and clone x location interactions. Starch content, however, is affected by season, location and clone x location interaction, but not by clone x season interaction. In other words, a clone with a high starch content in one season, may be expected to be superior in this trait relative to the other test clones in another season. This implies that starch content can profitably be used as a selection criterion

Table 10. Effect of clone and location on harvest data at 6 months from testing at three locations

Factor	Root yield (t/ha)	Harvest index	Starch content (%)	Starch yield (t/ha)
Clone				
CM 3371–22	20.8	0.53	22.9	4.9
CM 3380–10	23.2	0.56	23.3	5.5
CM 3388–15	19.2	0.53	22.0	4.4
CM 2527–7	19.6	0.44	22.6	4.6
CM 2975–21	20.0	0.50	21.8	4.5
CM 3299–26	21.3	0.55	23.8	5.1
CM 3906–31	34.0	0.68	20.5	7.2
CM 3707–31	22.7	0.53	22.4	5.2
CM 3906–13	23.7	0.55	22.0	5.4
CM 3898–6	22.2	0.49	22.3	5.1
CM 3855–37	21.2	0.55	23.6	5.2
CM 3303–21	16.4	0.47	22.4	3.7
C 5	16.7	0.42	21.6	3.7
Perintis	22.2	0.59	20.6	4.6
Mean	21.7	0.53	22.3	5.0
C.V.(%)	22.2	11.6	4.2	21.6
$LSD_{0.05}$	3.9	0.05	0.8	0.9
Location				
Pontian	27.8	0.54	23.8	6.6
Bkt. Tangga	11.2	0.54	19.8	2.2
Serdang	26.0	0.50	23.2	6.0
$LSD_{0.05}$	1.8	0.02	0.4	0.4

Table 11. Mean squares for variance components of four traits at 12 months from testing over three locations (MARDI Integrated Peat Research Station Pontian, MARDI research stations at Bukit Tangga and Serdang)

Source	df	Mean squares			
		Root yield	Harvest index	Starch content	Starch yield
Clones (C)	13	370.571**	0.0455**	23.776**	10.327
Locations (L)	2	1 824.589**	0.1038**	271.782**	128.095**
C x L	26	85.044	0.0104**	3.174**	5.783*
Replicate[L]	9	141.660*	0.0025	2.811**	11.554**
Error	117	56.422	0.0038	0.979	3.490

*Significant at probability level of $p = 0.05$
**Significant at probability level of $p = 0.01$

when selection is carried out over different seasons.

At 6 months, neither season nor location had significant effects on harvest index, but the interactions clone x season and clone x location affected this trait at both times of harvest. Fresh root yield, on the other hand, is influenced strongly by the clone x season interaction as well as by locations at both times of harvest.

Conclusions on CM 3906–31

CM 3906–31 is an early yielding clone by virtue of its high rate of root bulking, which

Table 12. Effect of clone and location on harvest data at 12 months from testing at three locations

Factor	Root yield (t/ha)	Harvest index	Starch content (%)	Starch yield (t/ha)
Clone				
CM 3371–22	38.0	0.60	24.8	9.4
CM 3380–10	40.6	0.60	24.1	9.7
CM 3388–15	42.8	0.68	23.4	10.0
CM 2527–7	43.2	0.54	24.7	10.8
CM 2975–21	39.8	0.56	24.3	9.9
CM 3299–26	43.6	0.59	25.4	11.0
CM 3906–31	56.2	0.69	20.4	11.6
CM 3707–31	39.0	0.52	24.4	9.5
CM 3906–13	42.0	0.58	24.7	10.4
CM 3898–6	47.3	0.62	24.9	11.7
CM 3855–37	38.6	0.61	25.9	10.0
CM 3303–21	38.2	0.54	25.2	9.6
C 5	33.8	0.47	24.4	8.2
Perintis	48.5	0.66	22.2	10.6
Mean	42.2	0.59	24.2	10.2
C.V.(%)	17.8	10.5	4.1	18.4
$LSD_{0.05}$	6.1	0.05	0.8	1.5
Location				
Pontian	48.3	0.62	23.0	11.1
Bkt. Tangga	37.0	0.54	22.9	8.4
Serdang	41.5	0.61	26.8	11.0
$LSD_{0.05}$	2.8	0.02	0.4	0.7

carries through to 12 months (especially on mineral soils in AEZ 3). This provides the flexibility, for harvesting either early or at the end of the normal 12-month period, to take advantage of prevailing prices for fresh roots. However under environmental conditions of moisture stress such as in AEZ 1, CM 3906–31 is unable to express its full productive potential when harvested early. Perintis shows marginally better tolerance to such conditions.

Another shortcoming is a lower starch content relative to C 5 and Black Twig, but starch yield per hectare at 6 months is still higher than these clones in AEZ 3 where there is no prolonged moisture stress throughout the cropping season. This starch yield advantage, however, disappears when harvest of the crop is delayed until 12 months.

Theoretical calculations of net income from early clones

Two scenarios will be examined relative to returns to be expected from using an early clone over the traditional 12-month cropping season: one, with regard to cultivation on drained peat, and two, on mineral soils.

To date, the highest yielding clone at 12 months in terms of both root and starch yields is Perintis (*Table 6* and *Table 8*). A comparison of the yields of Perintis and CM 3906–31 is given in *Table 13*.

Drained peat

Comparing a single 12-month cropping season with Perintis with two 6-month cropping seasons using CM 3906–31 *(Table 14)*, it may be seen that two 6-month crops of the early clone within a year bring in better net returns than a single crop of

Table 13. Six and 12-month yields of Perintis and CM 3906–31

	6-month yields (t/ha)		12-month yields (t/ha)	
	Root	Starch	Root	Starch
On peat				
Perintis	29.4	6.0	43.3	8.4
CM 3906–31	36.2	8.1	42.8	8.4
			72.4*	16.2*
On mineral soils				
Perintis	26.5	5.7	41.2	10.2
CM 3906–31	43.0	8.8	59.3	12.9
			86.0*	17.6*

*Computed yields of CM 3906–31 (6-month yields x 2)

Table 14. Costs and returns from a 12-month crop of Perintis vs. two 6-month crops of CM 3906–31 on drained peat

	Perintis 12-month season	CM 3906–31 Two 6-month seasons				
Costs ($/ha)*						
Land preparation	131	131	+	31		
Planting	100	100	+	100		
Weed control	312	312	+	312		
Fertilizers	944	944	+	794		
Subtotal	1 487	1 487	+	1 237	=	2 724
Harvesting @ $17/t						
Perintis 43 t/ha	731					
CM 3906–31 36 t/ha		612	+	612	=	1 224
Total costs	2 218					3 948
Returns ($/ha)						
Gross income at prices						
$83/t	3 486	2 988	+	2 988	=	5 976
$99/t	4 158	3 564	+	3 564	=	7 128
$116/t	4 872	4 176	+	4 176	=	8 352
Net income at prices						
$83/t	1 268					2 028
$99/t	1 940					3 180
$116/t	2 654					4 404

*Source: Tan (1987, with revisions to wage rate and input costs)

Perintis in the same time frame. Land preparation in the second season is confined to only chemical control of weeds as tillage is unnecessary (Tan 1991). Similarly, in the second season fertilizer costs are reduced because liming is unnecessary, having a residual effect lasting 3 to 5 years (Chew 1977).

The difference in profits from CM 3906–31 is in the region of $760/ha per year over those to be expected from Perintis at a root price of $83/t. At a root price of $116/t, this difference increases to $1 750/ha per year.

Mineral soils
Doing the same comparison for mineral soils, it will be appreciated that costs are not reduced in the second season unlike on peat *(Table 14)*. Effectively, costs are doubled when two crops are planted in one year. Since the costs of production are lower on mineral soils than on peat, the profits to be expected at the range of market prices for fresh roots are higher than those from cassava cultivation on peat. This is more so with CM 3906–31 which produces a higher fresh root yield at 6 months on mineral soils.

Thus, as in the case of cultivation on peat, the net returns from two crops of CM 3906–31 from the same piece of land in one year are higher than from a single crop of Perintis. The profit margins range from $1 838/ha to $3 323/ha per year at root prices ranging from $83/t to $116/t.

In practice, there may be a time lapse of 1–2 months between the harvest of the first crop to the planting of the second to allow

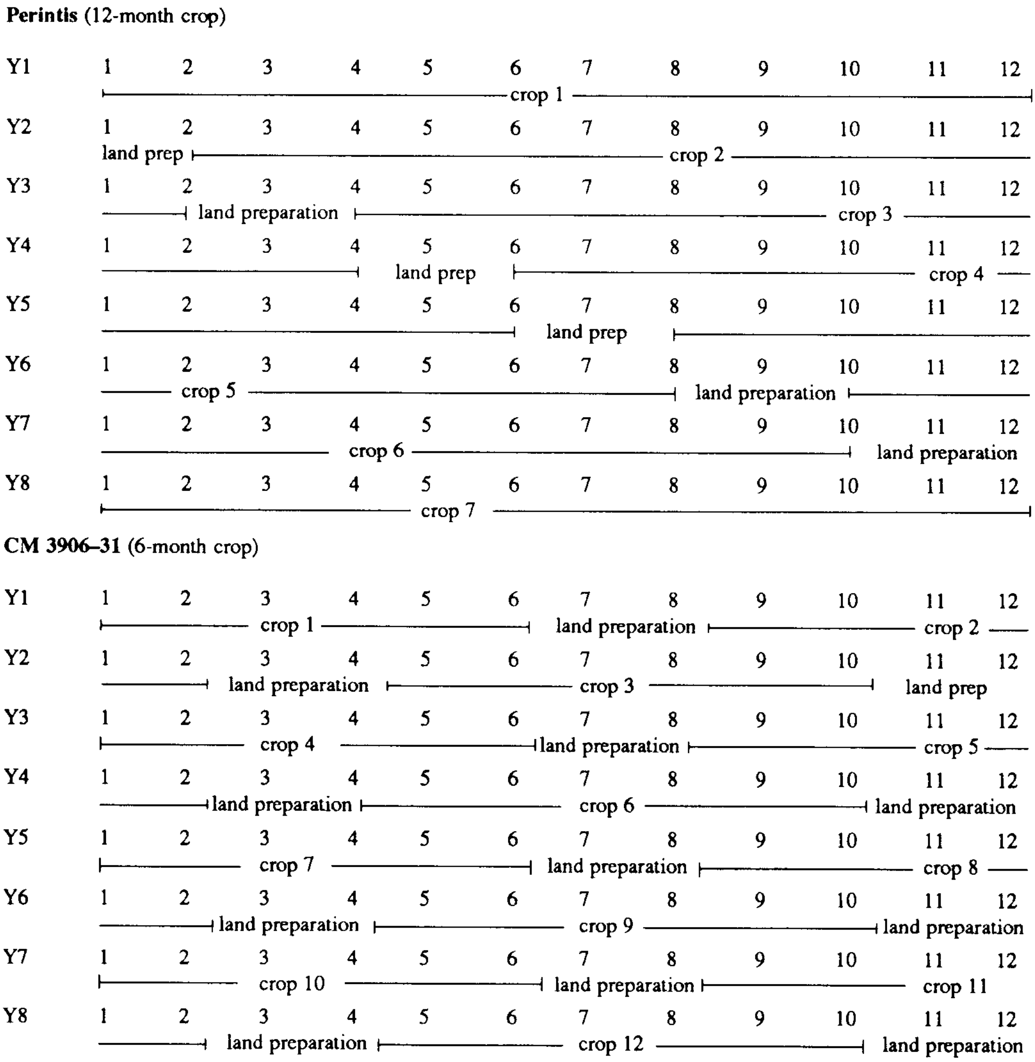

Figure 1. Crop scheduling for Perintis and CM 3906–31 over an 8-year cropping period

Table 15. Costs and returns from a 12-month crop of Perintis vs. two 6-month crops of CM 3906–31 on mineral soils

	Perintis 12-month season	CM 3906–31 Two 6-month seasons
Costs ($/ha)*		
Land preparation	250	500
Planting	100	200
Weed control	354	708
Fertilizers	428	856
Subtotal	1 132	2 264
Harvesting @ $17/t		
Perintis 41 t/ha	697	
CM 3906–31 43 t/ha		1 462
Total costs	1 829	3 726
Returns ($/ha)		
Gross income at prices		
$83/t	3 403	7 138
$99/t	4 059	8 514
$116/t	4 756	9 976
Net income at prices		
$83/t	1 574	3 412
$99/t	2 230	4 788
$116/t	2 927	6 250

*Source: Anon. (1988a)

Table 16. Costs and returns from seven 12-month crops of Perintis vs. 12 6-month crops of CM 3906–31 on mineral soils over an 8-year period

	Per crop	Perintis 7 crops	CM 3906–31 12 crops
Costs ($/ha)			
Land preparation	250	1 750	3 000
Planting	100	700	1 200
Weed control	354	2 478	4 248
Fertilizers	428	2 996	5 136
Subtotal	1 132	7 924	13 584
Harvesting @ $17/t			
Perintis 41 t/ha	697	4 879	
CM 3906–31 43 t/ha	1 462		8 772
Total costs	1 701	12 803	22 356
Returns ($/ha)			
Gross income at prices			
$83/t		23 821	42 828
$99/t		28 413	51 084
$116/t		33 292	59 856
Net income at prices			
$83/t		11 018	20 472
$99/t		15 610	28 728
$116/t		20 489	37 500
Difference ($/ha/year)			
@ $83/t			1 182
@ $99/t			1 640
@ $116/t			2 126

for land preparation, so that in fact two 6-month crops will take about 14 months. Bearing this in mind, over an 8-year period, it will be possible to get seven 12-month crops from Perintis or 12 6-month crops from CM 3906–31 *(Figure 1)*. Using the same basis as *Table 15* for calculations but adjusting for seven and 12 cassava crops respectively, CM 3906–31 will still give profits which are higher than those of Perintis by $1 182, $1 640 and $2 126/ha per year at the market prices of $83, $99 and $116/t respectively, for fresh roots *(Table 16)*.

Acknowledgements

The author is grateful to her assistant research officer, Mr Mohsin Yusof, and her research assistants, Mr Zainal Abidin Karim and Ms Inthirani R. at MARDI Research Station Serdang, Mr Ab. Majid Bakar and Mr Hasli Ali at MARDI Research Station Pontian, and Mr Jamaluddin Kasa at MARDI Research Station Bukit Tangga, for their active involvement at each step of clonal selection and evaluation.

She wishes also to acknowledge that the trial at Bukit Tangga was funded by a regional sub-project agreement No. 9–89 VICA under the auspices of the Asian Regional Cassava Research Program of CIAT (Centro Internacional de Agricultura Tropical).

References

Anon. (1988a). Anggaran kos pengeluaran dan pendapatan untuk tanaman dan ternakan, Techno-Economic and Social Studies Division, MARDI, Serdang *(mimeo.)*

—— (1988b). *CM 982–7: klon ubi kayu baru untuk tanah gambut* Serdang: MARDI (brochure)

Chan, S. K., Khelikuzaman, M. H., Tan, S. L., Geh, S. L. and Lo, N. P. (1983). *Cassava in Peninsular Malaysia: with particular reference to production techniques* (a special report) 97 p. Serdang: MARDI

Chew, W. Y. (1977). Assessment of cassava as an industrial crop on Malaysian peat. *MARDI Rep. No.* **57** 12 p. Serdang: MARDI

Cobley, L. S. (1963). Starch storage crops In: *An introduction to the botany of tropical crops* Chap. VI. p. 174–7. London: Longmans, Green and Co. Ltd.

Nieuwolt, S., Ghazalli, M. Z. and Gopinathan, B., n.d. [1982]. *Agro-ecological regions in Peninsular Malaysia* 20 p. Serdang: MARDI

Noor Auni, H. and Tan, S. L. (1980). Perbandingan di antara cara-cara menentukan kandungan kanji di dalam ubi kayu (*Manihot esculenta* Crantz). *Teknol. Pertanian, MARDI 1:* 30–4

Purseglove, J. W. (1974). *Tropical crops: Dicotyledons* p. 172-80. London: Longman

Tan, S. L. (1987). CM 982–7: a new cassava clone recommended for cultivation on peat. *Teknol. Pelbagai Tanaman, MARDI 3:*1–5

—— (1989a). Prestasi klon ubi kayu Perintis (CM 982-7) di pelbagai lokasi. *Teknol. Pelbagai Tanaman, MARDI 5:* 23–6

—— (1989b). The root of the problems in cassava breeding *Proc. plant and animal breeding workshop* 7–9 Oct. 1986, Serdang (Ahmad Zamzam, M. and Tan, S. L., ed.) p. 131–8. Serdang: MARDI

—— (1991). Minimal tillage in cassava cultivation on drained peat. *MARDI Res. J. 19(1):* 1–7

Tan, S. L., Chan, S. K. and Yeong, S. W. (1989). Potential uses of cassava and projections on national requirements. Paper presented at workshop: Cassava production on a commercial scale, 16 Nov. 1989, Serdang, 12 p. Organizer: MARDI

Accepted for publication on 21 August 1991