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Reduction of fertilizer use by planting an early variety of cassava (*Manihot esculenta* Crantz)

[Mengurangkan penggunaan baja dengan menanam varieti ubi kayu (*Manihot esculenta* Crantz) cepat matang]

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Key words: cassava, *Manihot esculenta* Crantz, fertilizer rate, frequency of application, early variety, leaf nutrient uptake

Abstrak

Penggunaan baja untuk ubi kayu (biasanya tanaman 12 bulan), terutama yang ditanam di tanah gambut bersaliran, menyumbangkan sebahagian besar (34%) daripada kos pengeluaran. Kadar yang disyorkan ialah 250 kg N, 30 kg P_2O_5 and 160 kg K_2O sehektar, bersama-sama $CuSO_4.5H_2O$ (ditabur di atas tanah pada kadar 10 kg/ha atau dibekalkan dengan cara merendam keratan ubi kayu di dalam larutan 2% sebelum menanam).

MARDI mengisytiharkan varieti ubi kayu cepat matang yang dinamakan MM 92 pada tahun 1992. Varieti ini istimewa kerana berupaya mengeluarkan hasil sebanyak 30–35 t/ha dalam tempoh 6 bulan. Hasil ini setanding dengan hasil varieti komersil Black Twig dalam tempoh 12 bulan.

Dalam usaha mengurangkan kadar pembajaan yang tinggi, ujikaji telah dijalankan. Dalam ujikaji ini, kadar atau kekerapan pembajaan MM 92 (tanaman 6 bulan) dikurangkan selama enam musim penanaman. Sembilan amalan pembajaan dikaji dengan dua daripadanya sebagai kawalan. Kawalan yang pertama melibatkan pemberian kadar baja penuh pada setiap musim (100%). Kawalan yang kedua adalah dengan cara tidak membaja selama enam musim penanaman (0%). Tiga perlakuan menerima baja separuh daripada jumlah untuk kawalan yang pertama dalam tempoh enam musim penanaman (50%). Satu perlakuan menerima satu pertiga (33.3%), dua lagi menerima satu suku (25%), manakala perlakuan yang terakhir menerima 16.7% kadar penuh, mengikuti beberapa gabungan kadar dan kekerapan.

Hasil ujikaji menunjukkan bahawa baja dapat dikurangkan dengan banyak tanpa menjejaskan hasil ubi varieti MM 92. Musim yang pertama dan yang kedua tidak menunjukkan perbezaan yang ketara antara perlakuan, mungkin kerana kesan sisa baja daripada amalan pembajaan lepas di tapak ujikaji itu. Perbezaan yang ketara antara perlakuan kelihatan pada musim yang ketiga. Hasil ubi yang lebih tinggi dicatatkan oleh tiga perlakuan iaitu kawalan yang pertama, separuh kadar baja setiap musim (50%) atau berselang musim (25%). Kandungan bahan kering dalam ubi tidak dipengaruhi oleh perlakuan baja selama enam musim penanaman. Oleh yang demikian, apabila menanam varieti MM 92 untuk mengutip hasil setiap 6 bulan, kos pembajaan boleh dikurangkan sebanyak 73.3% (penjimatan wang sebanyak RM3 216/ha) dalam tempoh enam musim penanaman tanpa menjejaskan hasil ubi.

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Kandungan N daun lebih berpengaruh daripada kandungan P atau K daun. Dalam hampir semua perlakuan, kedua-dua kandungan P dan K didapati melebihi tahap genting yang dilaporkan untuk hasil ubi yang optimum. Tahap genting bagi N daun (pada 95% hasil maksimum) kajian ini ialah kira-kira 5.5%.

Abstract
Fertilizer use for cassava (traditionally a 12-month crop), particularly when planted on drained peat, constitutes a large component (34%) of production costs. The recommended rate has been 250 kg N, 30 kg P_2O_5 and 160 kg K_2O per hectare, supplemented by $CuSO_4.5H_2O$ (either soil-applied at 10 kg/ha, or supplied by dipping cassava cuttings in 2% solution before planting).

MARDI released an early variety of cassava named MM 92 in 1992. This variety is unique in its capability of producing a 6-month fresh root yield of 30–35 t/ha, which is comparable with what is produced by the commercial variety Black Twig in 12 months.

In an attempt to reduce the high rate of fertilizer application, a fertilizer trial was conducted, in which the rate or the frequency of fertilizer application was reduced during six cycles of a 6-month crop of MM 92. Nine fertilizer practices were tested, two of which were controls. The first control comprised the full rate of fertilizers, applied at each crop cycle (100%). The second control was a treatment receiving no fertilizers over the six cycles (0%). Three treatments received half of the full rate of fertilizers over the six cycles (50%). One treatment received one-third (33.3%), two others received one-quarter (25%), while the remainder received 16.7% of the full rate, all through various combinations of rate and frequency.

Results of the trial showed that fertilizers may be reduced substantially without compromising root yield in MM 92. The first and second cycles did not reveal any significant treatment differences, presumably due to residual effects of past manuring history on the site. Significant differences among treatments showed up by the third cycle. Significantly higher yields (ranging from 29.2 to 30.6 t/ha per season) were recorded by three treatments, namely the first control of full rates applied every season, half the rate applied every season (50%) or every other season (25%). Dry matter content of the roots was not affected by the fertilizer treatments throughout the six cropping seasons. Thus, fertilizer costs, when growing variety MM 92 for 6-month harvests, may be reduced by as much as 73.3% (a saving of RM3 216/ha) over a six-cycle cropping without jeopardizing root yields.

Leaf N level has a greater influence on root yield than leaf P or K, both of which were above the reported critical levels for optimum yield in practically all the treatments. The critical leaf N (at 95% maximum yield) in this study was found to be around 5.5%.

Introduction

While planting cassava on mineral soils has been a traditional practice in Malaysia, mainly geared towards the starch extraction industry, planting on drained peat is a recent recommendation. The need to move from mineral soil cultivation is brought about by the increasing pressure on available arable farmland by many crops, particularly perennial tree crops which at present account for 88% of cultivated land area in Peninsular Malaysia (Mohamad and Siew

1994). Cassava, with its low-value status, is obviously less competitive.

Research at MARDI has shown the feasibility of growing cassava on peat, given adequate drainage infrastructure and land-clearing from the virgin peatland forest. However, to render the environment appropriate for cassava, increased fertilizer inputs, particularly lime (to correct soil pH) and nitrogen (to overcome the inherent high C/N ratio of peat), are necessary. Lime input for cassava on peat is not substantial (3 t dolomitic lime/ha), since the crop has a high tolerance for acidity. For a 12-month crop of cassava, it has been recommended that the rate of 250 kg N, 30 kg P_2O_5 and 160 kg K_2O per hectare be adopted (Tan and Chan 1989). Lately, an estimation of costs to produce cassava by manual means on peat based on actual field data showed fertilizer costs (including application) to amount to RM731/ha, accounting for 34% of total production costs (Tan and Chan 1995).

Growing cassava on drained peat has not been widely adopted yet, and it is envisaged that a reduction in costs will make the undertaking a more attractive venture. The possibility of reducing fertilizer costs presented itself with the release by MARDI in 1992 of a new, early harvestable cassava variety named MM 92. This variety adapts well to peat and produces a fresh root yield of 30–35 t/ha after 6 months (Anon. 1992). It seems possible that being shorter term in growth, the variety would require less fertilizer than would a 12-month variety such as Black Twig, the most popular commercial variety. Furthermore, tropical woody peat having a high cation exchange capacity is supposed to retain applied nutrients well, suggesting a residual effect when applying fertilizers.

A fertilizer trial was therefore designed in an attempt to reduce the high rate of fertilizer application to cassava grown on peat, through manipulation of the rate or the frequency of application.

Materials and methods

The effects of reduced fertilizer application on early cassava variety MM 92 was monitored over six crops of 6-month duration each, hereafter to be referred to as seasons. The trial was located at the MARDI Peat Research Station in Pontian, in the southern part of Peninsular Malaysia. Nine fertilizer practices were tested, two of which were controls. One control comprised the application of the full rate of fertilizers every season (100%). The second control was a treatment receiving no fertilizers whatsoever throughout the six seasons (0%). The other seven treatments received 16.7% to 50% of the amount applied to Control 1 over the six seasons. Details are given in *Table 1*.

Table 1. Fertilizer treatments concerning the rate or frequency of application to cassava over six seasons of cropping

Treatment	Application rate over 6 seasons*						Percent Control 1
	1st	2nd	3rd	4th	5th	6th	
1 (Control 1)	1	1	1	1	1	1	100.0
2	1	0	1	0	1	0	50.0
3	1	0	0	1	1	0	50.0
4	1	0	0	0	1	0	33.3
5	$^1/_2$	$^1/_2$	$^1/_2$	$^1/_2$	$^1/_2$	$^1/_2$	50.0
6	$^1/_2$	0	$^1/_2$	0	$^1/_2$	0	25.0
7	$^1/_2$	0	0	$^1/_2$	$^1/_2$	0	25.0
8	$^1/_2$	0	0	0	$^1/_2$	0	16.7
9 (Control 2)	0	0	0	0	0	0	0.0

*6 months each
1: full rate of fertilizers
$^1/_2$: half the rate of fertilizers
0: no fertilizers applied

The treatments, replicated four times, were arranged in a randomized complete block design. A plot size of 8.0 m x 8.0 m was used with plant spacing at 1.0 m x 1.0 m, giving a sample size of 36 plants/plot.

Dolomitic limestone was applied at 3 t/ha one month before planting in the first season to correct soil pH (from 3.8) to around 4.0. This lime application was repeated before planting in the fifth season. Mature stem cuttings of 20 cm length of the variety MM 92 were used for planting. The cuttings were dipped in 2% copper sulphate solution for 10 min before planting every season, as recommended by Chan and Ramli (1987) to correct the inherent Cu deficiency in peat. Fertilizers (following *Table 1*) were applied at planting, by banding along the side of the planted row.

Peat composite samples were collected from each replicate before the start of the first cropping season, and subsequently at the end of each cropping season. The samples were analyzed for contents of N (by microKjedahl method), P (by Bray II method) and K (by NH_4 acetate method).

Similarly, for each season, samples of the sixth fully expanded leaf (excluding the petioles) were collected at 3 months after planting, and chemically analyzed for concentrations of N, P and K.

All crops were harvested after 6 months and data were collected on the fresh root weight per plot, converted to yield per hectare, as well as on dry matter content of the roots, estimated from samples oven-dried at 70 °C. Dry matter content of the roots reflects their starch content (Noor Auni and Tan 1980). Monthly rainfall data at the station over the period of study were also recorded.

Results and discussion

Crop performance

Data per season on fresh root yield and dry matter content were analyzed separately, as were data on cumulative root yields over the six seasons. No significant differences in yield were noted in the first two seasons *(Table 2* and *Figure 1)*, possibly due to residues from fertilizers applied to other crops grown before the trial. Significant differences, however, were obtained from the third to the sixth seasons *(Table 3)*.

Table 2. Analyses of variance on fresh root yields due to nine different fertilizer treatments on cassava over the first two seasons of cropping

Source	df	Mean squares	
		1st season	2nd season
Replications	3	4.650ns	21.576ns
Treatments	8	12.555ns	32.281ns
Error	24	5.319	15.165

ns = not significant

In the third season, the treatments where the full (1-0-1) or half ($^1/_2$-0-$^1/_2$) rate was applied only in the first and third seasons, and where the half rate was applied every season ($^1/_2$-$^1/_2$-$^1/_2$) gave yields not significantly different from the control 1-1-1. In the fourth season, three treatments recorded yields not significantly different from Control 1, but significantly different from Control 2 (which did not receive any fertilizers at all). These were the treatments receiving half the rate every season ($^1/_2$-$^1/_2$-$^1/_2$-$^1/_2$), every other season ($^1/_2$-0-$^1/_2$-0) or once in every three seasons ($^1/_2$-0-0-$^1/_2$).

In the fifth season *(Table 3)*, all the plots receiving fertilizers had significantly higher yields than Control 2 (zero fertilizers), while five treatments were not significantly different from Control 1. The two treatments where two or three seasons of zero fertilizer followed the application of only half the rate had significantly lower yields. By the sixth season, it was obvious that half the fertilizer rate was capable of sustaining as high a root yield as the full rate applied every season. Not significantly different from the former were the treatments receiving half rate every other crop, and (surprisingly!) either the full or half rate following three seasons of zero fertilizer. By contrast, the treatments receiving either the full or half rate following two seasons of zero fertilizer had yields as low as Control 2.

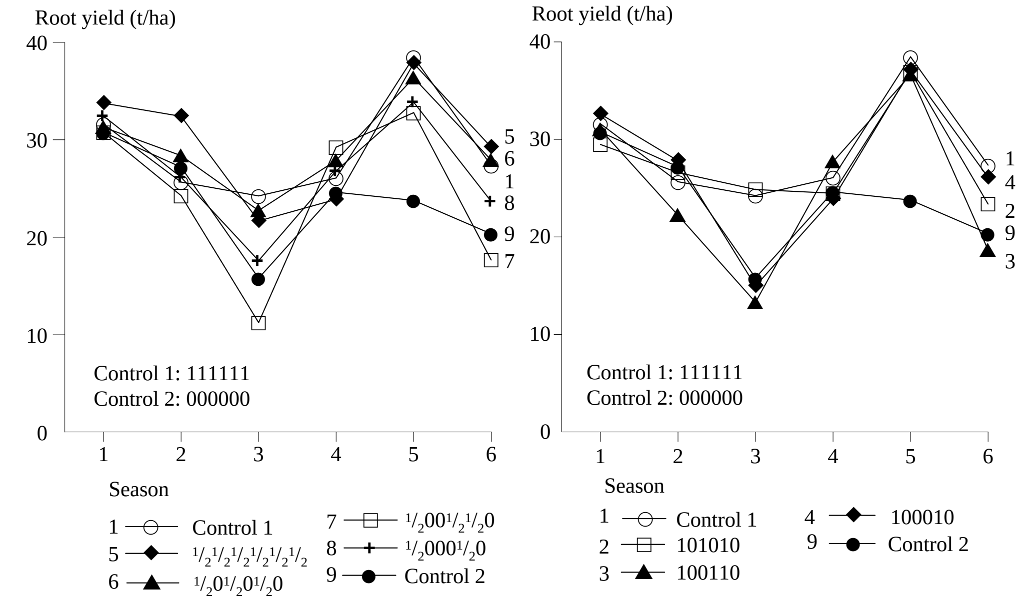

Figure 1. Fresh cassava yield at different rates and frequencies of fertilizer application over six seasons on peat soil in Pontian Station, Malaysia, 1991–1995

Table 3. Mean fresh root yields of cassava receiving nine different fertilizer treatments

Fertilizer treatment	Fresh root yield (t/ha)	Fertilizer treatment	Fresh root yield (t/ha)
Third season		Fourth season	
1-1-1[1]	24.2a	1-1-1-1[1]	26.1abc
1-0-1	24.9a	1-0-1-0	24.5c
1-0-0	13.3de	1-0-0-1	27.7ab
1-0-0	15.0cde	1-0-0-0	23.9c
1/2-1/2-1/2	21.7ab	1/2-1/2-1/2-1/2	28.7a
1/2-0-1/2	22.7a	1/2-0-1/2-0	27.9a
1/2-0-0	11.2e	1/2-0-0-1/2	29.3a
1/2-0-0	17.6bc	1/2-0-0-0	26.8abc
0-0-0[2]	15.8cd	0-0-0-0[2]	24.6bc
Fifth season		Sixth season	
1-1-1-1-1[1]	38.5a	1-1-1-1-1-1[1]	27.4ab
1-0-1-0-1	36.9abc	1-0-1-0-1-0	23.4bc
1-0-0-1-1	36.6abc	1-0-0-1-1-0	18.7cd
1-0-0-0-1	37.1abc	1-0-0-0-1-0	26.1ab
1/2-1/2-1/2-1/2-1/2	37.8ab	1/2-1/2-1/2-1/2-1/2-1/2	29.2a
1/2-0-1/2-0-1/2	36.4abc	1/2-0-1/2-0-1/2-0	27.9ab
1/2-0-0-1/2-1/2	32.8c	1/2-0-0-1/2-1/2-0	17.7d
1/2-0-0-0-1/2	33.9bc	1/2-0-0-0-1/2-0	23.7abc
0-0-0-0-0[2]	23.8d	0-0-0-0-0-0[2]	20.4cd

[1] Control 1 (full rate every cycle)
[2] Control 2 (no fertilizers every cycle)

1: full rate of fertilizers
1/2: half the rate of fertilizers
0: no fertilizers applied

Yields within a column with the same letter are not significantly different from one another according to the LSD test ($p \leq 0.05$)

No significant differences in dry matter content due to fertilizer treatments were apparent throughout the six seasons of cropping *(Table 4)*.

Looking at yield trends over the six seasons *(Figure 1)*, two features are apparent. Yields of Control 2 which received no fertilizer throughout the trial, became well separated from those of Control 1 which received the full rate throughout, after the second season. This implies that any residual fertilizer from a crop or crops previous to the trial was exhausted by this time. The third season appeared to be critical for fresh root yields in general, when poorer fertilizer treatments stood out clearly. It is not clear what were the predisposing environmental conditions; rainfall pattern in relation to crop cycle did not provide proof of any influence on yield *(Figure 2)*. Under such circumstances, Control 1 was able to sustain the yield of the second season. In this third season, all the treatments which received no fertilizer for two consecutive seasons, had yields significantly lower than Control 1. Yields recovered dramatically in the fourth season, especially when the fertilizer application resumed for treatments 1-0-0-1 and $^1/_2$-0-0-$^1/_2$.

In the fifth season, yields improved to more than 30 t/ha in all the treatments except Control 2, in many cases exceeding the yields in the first season. This could probably be due to the effects of liming before planting in the fifth season, since liming has been known to mineralize nutrients in the peat substrate, thus boosting the availability of such nutrients as nitrogen, phosphorus and potassium for crop uptake (Chakraborty et al. 1961; Ahmad et al. 1990). This phenomenon has also been reported by Tan and Chan (1989). That there

Table 4. Analyses of variance on root dry matter contents due to nine different fertilizer treatments on cassava, as well as minimum and maximum values, over six seasons of cropping

Source	df	Mean squares per cropping season					
		1st	2nd	3rd	4th	5th	6th
Replications	3	92.520**	88.986**	3.461ns	17.631ns	14.863ns	14.702ns
Treatments	8	7.543ns	17.371ns	28.237ns	7.457ns	15.070ns	15.463ns
Error	24	17.534	18.424	17.799	11.677	9.788	15.549
Minimum value		26.9	23.2	21.7	19.2	25.3	25.0
Maximum value		30.8	28.9	30.5	23.7	30.7	31.5

**significant at $p \leq 0.01$
ns = not significant

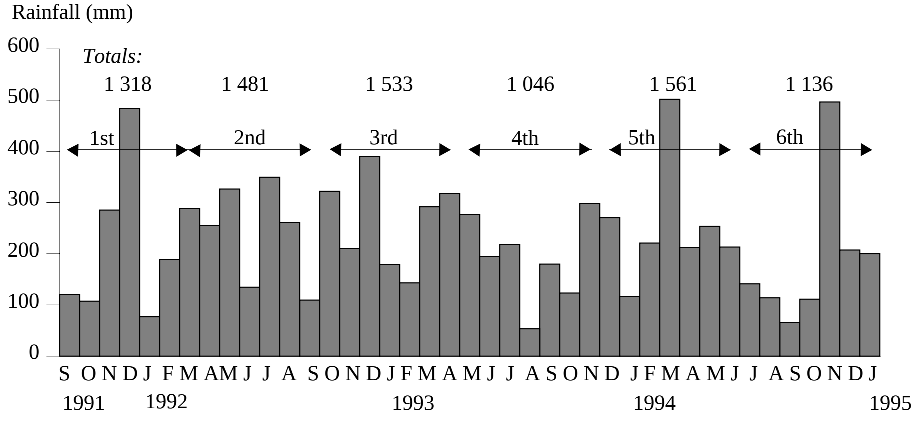

Figure 2. Rainfall (per month per cropping season) throughout the study period

was no response to liming in Control 2 seems to indicate that the nutrients in this case were too near depletion from lack of fertilizer input over five seasons.

A differentiation in yields, similar to that observed in the third season, was discernible once again in the sixth season, especially for those treatments with only half the rate applied infrequently.

Statistical analyses of cumulative fresh root yields over the six seasons of cropping showed that six treatments had similar yields to Control 1 and significantly different yields from Control 2 *(Figure 3)*. However, more pertinent is the fact that top three treatments were those where half the fertilizer rate was applied every season ($^1/_2$-$^1/_2$-$^1/_2$-$^1/_2$-$^1/_2$-$^1/_2$) or every other season ($^1/_2$-0-$^1/_2$-0-$^1/_2$-0), and where the full rate was applied every season. The implication is that fertilizer costs may be reduced by half or three-quarters without sacrificing yield. This conclusion is strengthened further when cumulative dry root yields are considered. Dry root yield may be computed from the product of fresh root yield and dry matter content. The treatment receiving half the fertilizer rate every season in fact produced a significantly higher cumulative dry root yield than the treatment receiving the full rate *(Figure 4)*. Alternatively, this half rate may be applied every other season since the cumulative dry yield obtained was no worse.

Nutrient status

Peat samples Contents of N, P and K in the peat samples *(Table 5)* show what happens over the six seasons of cropping. The boost in contents of all three nutrients in the second season suggests that liming helped in their mineralization. There is subsequently a general trend of depletion of these nutrients with consecutive croppings until the fifth season when a smaller boost occurred, particularly for N and K, following a second liming.

Critical levels of major nutrients in the soil for cassava are 6–10 ppm P and 0.09–0.15 meq. K/100 g (Howeler 1985).

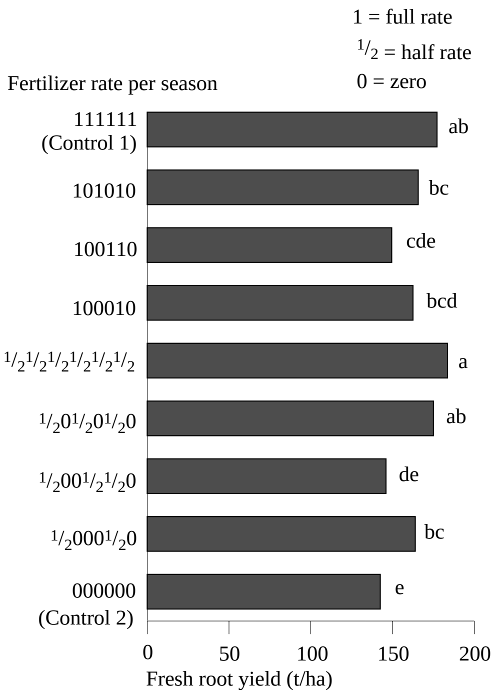

Figure 3. Cumulative fresh root yields over six seasons at different rates and frequencies of fertilizer application

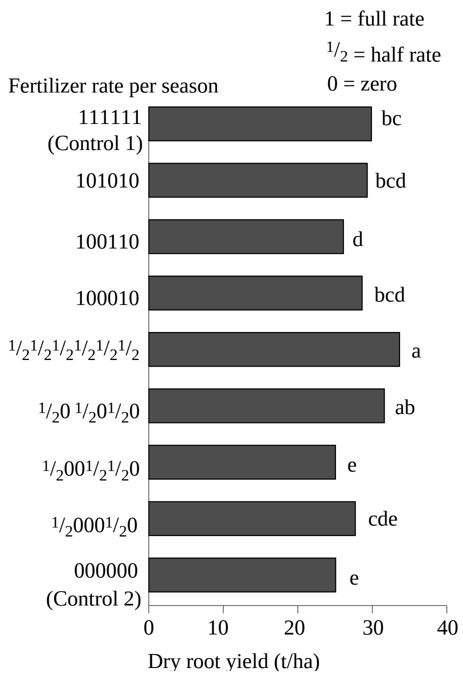

Figure 4. Cumulative dry root yields over six seasons at different rates and frequencies of fertilizer application

Table 5. Contents of N, P and K in peat samples collected before the first season of cropping and after each subsequent season of cropping

Fertilizer treatment	N content (%) by microKjedahl method						P content (ppm) by Bray II method						K content (meq./100 g) by NH_4 acetate method					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1-1-1-1-1-1		1.46	1.40	0.98	1.02	1.20		35	35	16	15	19		0.57	0.42	0.24	0.32	0.14
1-0-1-0-1-0		1.42	1.42	1.02	1.05	1.20		32	30	14	10	24		0.52	0.41	0.25	0.16	0.18
1-0-0-1-1-0		1.46	1.42	1.02	1.00	1.10		28	29	13	16	13		0.71	0.43	0.18	0.48	0.20
1-0-0-0-1-0		1.40	1.42	1.00	1.07	1.17		30	31	10	11	10		0.55	0.39	0.14	0.24	0.11
$^1/_2$-$^1/_2$-$^1/_2$-$^1/_2$-$^1/_2$-$^1/_2$		1.42	1.39	0.99	1.04	1.20		32	30	14	12	8		0.62	0.45	0.14	0.25	0.11
$^1/_2$-0-$^1/_2$-0-$^1/_2$-0		1.46	1.40	0.96	1.03	1.12		29	32	16	8	8		0.45	0.54	0.19	0.26	0.14
$^1/_2$-0-0-$^1/_2$-$^1/_2$-0		1.40	1.43	1.01	1.00	1.28		26	30	17	12	14		0.62	0.71	0.16	0.32	0.16
$^1/_2$-0-0-0-$^1/_2$-0		1.43	1.44	1.03	1.02	1.22		31	36	8	10	5		0.70	0.73	0.15	0.17	0.10
0-0-0-0-0-0		1.44	1.41	1.03	1.01	1.20		33	28	6	8	5		0.48	0.40	0.13	0.15	0.08
Mean	1.17	1.43	1.41	1.00	1.03	1.19	12	31	31	13	11	12	0.40	0.58	0.50	0.18	0.26	0.14

Table 6. Concentrations of N, P and K in the leaf samples (sixth fully expanded leaves without petioles) collected at 3 months after planting from each season of cropping

Fertilizer treatment	N concentration (%)						P concentration (%)						K concentration (%)					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1-1-1-1-1-1	5.90	5.31	4.72	5.19	5.78	5.38	0.40	0.38	0.37	0.36	0.37	0.37	1.80	1.53	1.58	1.62	1.80	1.71
1-0-1-0-1-0	5.82	4.94	4.71	4.64	5.76	4.91	0.44	0.35	0.39	0.32	0.36	0.36	1.87	1.53	1.60	1.35	1.71	1.40
1-0-0-1-1-0	5.93	4.83	4.49	5.30	5.66	4.82	0.42	0.37	0.34	0.35	0.37	0.35	1.88	1.58	1.53	1.58	1.75	1.47
1-0-0-0-1-0	5.84	4.87	4.44	4.57	5.84	4.71	0.42	0.38	0.35	0.30	0.36	0.34	1.83	1.52	1.45	1.38	1.77	1.39
$^1/_2$-$^1/_2$-$^1/_2$-$^1/_2$-$^1/_2$-$^1/_2$	5.82	5.05	4.66	5.13	5.54	4.95	0.41	0.38	0.36	0.34	0.35	0.35	1.78	1.49	1.50	1.48	1.70	1.50
$^1/_2$-0-$^1/_2$-0-$^1/_2$-0	5.82	4.78	4.52	4.54	5.52	4.80	0.38	0.38	0.36	0.30	0.34	0.33	1.70	1.45	1.54	1.38	1.63	1.39
$^1/_2$-0-0-$^1/_2$-$^1/_2$-0	5.64	4.99	4.33	4.94	5.50	4.43	0.38	0.34	0.32	0.32	0.36	0.33	1.72	1.57	1.41	1.45	1.64	1.32
$^1/_2$-0-0-0-$^1/_2$-0	5.83	4.74	4.47	4.53	5.53	4.90	0.40	0.35	0.35	0.38	0.34	0.34	1.74	1.52	1.51	1.30	1.65	1.41
0-0-0-0-0-0	5.51	4.95	4.47	4.67	5.38	4.80	0.37	0.36	0.34	0.29	0.32	0.31	1.61	1.50	1.46	1.34	1.45	1.32

P and K contents dropped to critical levels in some of the treatments from the fourth season onwards. Soil N content is less indicative of what is available to the crop (because of the high C/N ratio of peat).

Leaf samples Concentrations of major nutrients in the leaf samples give a picture of the fertility status of the soil and the nutrients available for uptake by the crop. From *Table 6*, it may be seen that generally there was a noticeable drop in the concentrations of all three nutrients after the first season. As in the peat data, it would appear that liming in the beginning of the trial and before the fifth season helped to mineralize the nutrients, particularly N and K, and enhanced their uptake.

Howeler (1983) had suggested that when the N content in leaf samples was less than 4.7%, this nutrient is deficient (the critical level being set at 80% of maximum yield). This appeared to be the case when no fertilizer was applied for two or three consecutive seasons. It also showed up in the third and the fourth seasons when only half the rate was applied every alternative season ($^1/_2$-0-$^1/_2$-0), implying that this rate did not leave sufficient nitrogen in the peat for uptake in subsequent seasons when no fertilizer was applied.

Yield data over the six seasons when regressed against leaf N data showed a quadratic relationship ($y = -196.26 + 77.04x - 6.46x^2$) with a goodness of fit of 82.9% (linear regression had a correlation of 80.6). Yield data recalculated as a percentage of the computed maximum yield were plotted against leaf N *(Figure 5)* to give a critical leaf N level (at 95% maximum yield) of approximately 5.5%. This would explain why yields declined from the second to the fourth seasons, and again in the sixth season when leaf N concentrations in all treatments were less than 5.5%. At 80% maximum yield, the critical leaf N level was between 4.9% and 5.0%, somewhat higher than what was suggested by Howeler (1983).

It was noted that even in Control 1 where the full fertilizer rate was applied every season, leaf N was unable to sustain itself above the 95% critical level from the second to the fourth seasons, and in the sixth season *(Table 6)*. This might be explained by the possible interaction with other nutrients (such as Ca and Mg) which are insufficient, resulting in restricted uptake. Tan and Chan (1995) have reported this phenomenon in a study involving a 12-month variety Black Twig.

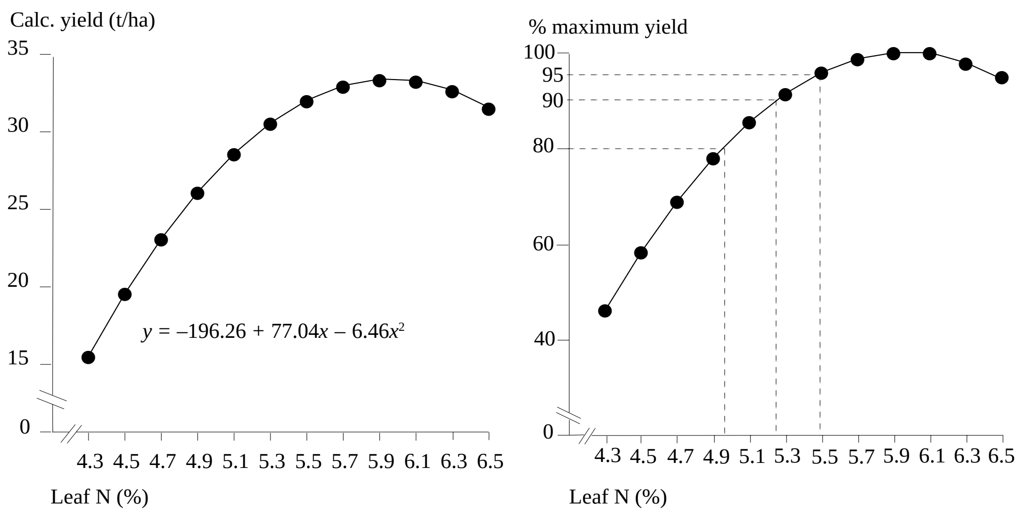

Figure 5. Fitted curve of fresh root yield data vs leaf N content

Additionally, in the third season, all those fertilizer treatments resulting in a N content less than that of Control 1 *(Table 6)*, produced a lower root yield *(Table 3)*. These yield reductions were significant when the leaf N content was less than 4.5% *(Table 3)*. Short supply of nitrogen can be simply a low status level in the soil or impeded uptake due to unfavourable weather conditions.

Unlike the peat data, the leaf analyses showed that P was generally sufficient over the duration of the study, except in the fourth season in Control 2 where no fertilizers had been applied throughout. In this instance, the P concentration was less than 0.30%, considered the critical level (Howeler 1983). Similarly, K was not limiting in any of the treatments (including Control 2) throughout the whole study since the leaf concentrations all exceeded the critical level of 1.0% (Howeler 1983). That these two nutrients were not limiting was borne out by the lack of goodness of fit ranging from only 39.2% to 63.3% when the data were regressed with yield to a linear or quadratic model (equations not shown).

It may be surmised that N is by far a more important element in the nutrition of cassava on drained peat than P and K, having significant yield-depressing consequences when in short supply.

Rainfall Data on rainfall per month and totals per 6-month cropping period over the six seasons of cropping are presented in *Figure 2*. There were neither significant correlations between the amount of rain which fell within each season with the mean fresh root yield recorded in that particular season (r = 0.12), nor with the mean fresh root yield of each treatment (r values ranging from –0.10 to 0.58). This is in agreement with what was reported by Tan and Normah (1995). Thus, the generally lower yields in the third season cannot be explained by less or more rain than in the other seasons.

Cost implications It appears that fertilizer costs may be saved substantially when growing the early variety MM 92 since only half or quarter the rate which hitherto has been recommended for 12-month cassava varieties would be required. If the half rate was applied every season MM 92 was planted, this incurs costs totalling RM2 340/ha for the fertilizers (RM341 x 6) plus the labour (RM49 x 6) to apply them over the six seasons of cropping. By contrast, using the full rate every season would cost RM4 386/ha for the same period (Tan and Chan 1995). Thus, there would be savings of RM2 046/ha for six seasons or RM341/season.

If the half rate was applied every other season, the costs incurred would amount to only RM1 170, since even the labour cost of application will also be saved. This translates into savings worth RM3 216/ha. Thus, if the total costs of cassava production on peat used to be RM2 134/ha per season, by planting the early variety MM 92 and practising reduced fertilizer rate as well as reduced frequency of application, costs would be reduced by 25% per season. Savings in labour wherever possible are important in Malaysia, where the agricultural sector is often plagued by labour shortages.

Conclusion

While the yield data show that fertilizer use when growing cassava variety MM 92 on drained peat may be reduced by halving the rate or applying less frequently, data on nutrient levels in the peat medium over continuous cropping should not be ignored. Although leaf analyses did not generally show nutrient concentrations falling below the critical levels, this might simply be a reflection of how well MM 92 is able to extract these nutrients from the peat. The declining contents, especially for P and K when less fertilizers are applied, may be considered a warning of nutrient depletion. In other words, the nutrient status in the peat will probably need to be replenished in the long run: either by reverting to higher fertilizer rates, or liming (which seems to aid mineralization), or better still by crop rotation after several seasons of planting cassava.

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