Variation of Leaf Nutrient Concentrations in Oil Palm Genotypes and Their Implication on Oil Yield[1]

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ABSTRACT

Variations of leaf nutrient concentrations were detected in four clonal oil palm materials namely, AVROS, Yangambi, La Me and NIFOR as well as two D×P hybrid Yangambi that were planted in Pahang, Malaysia. There were significant differences in all leaf nutrient concentrations for all the planting materials. Leaf potassium (K) concentration for D×P hybrid Yangambi-DQ8 was consistently lower than AVROS-A122 by almost 15-20% in all the growing conditions. In contrast, the leaf K contents for Yangambi-DQ8 and Yangambi-Y103 were comparable to that of AVROS-A122, and these three planting materials produced the highest oil yields of more than 8.7 tonnes/hectare of total economic product. These three planting materials consistently recorded higher total leaf cation concentrations over eight-year period except for *Yangambi-Y103 at 5-8 years after planting. In view of high current fertilizer cost, selecting oil palm genotypes that are able to produce good oil yields on lower fertilizer inputs and giving consistent leaf nutrition need to be given consideration.*

Keywords: *Leaf nutrients, oil palm, clones*

[1] Paper presented at the International *Seminar on Breeding for Sustainability in Oil Palm, held on* 18 November 2011 in Kuala Lumpur, Malaysia. Jointly organised by the International Society for Oil Palm Breeders (ISOPB) and Malaysian Palm Oil Board (MPOB). P. 71 - 85

INTRODUCTION

In Malaysia, oil palm has been planted on almost over five million hectares of land and grown under very diverse agro-climatic environments (MPOB, 2011). In addition to sustaining high oil yield through selected elite planting materials, these palms must be able to grow well under marginal conditions and incorporated with good agronomic practices to assure that respectable yields can be achieved. The main thrusts of breeding programmes have been outlined by Rajanaidu *et al.* (2000), such as (i) improve oil yield, (ii) shorter palm height, (iii) disease resistance, (iv) desired physiological traits (bunch number, total dry matter and bunch dry matter) and (v) exploitation of G×E interactions. In order to further strengthen the breeding programmes, the Malaysian Palm Oil Board (MPOB) has drawn up more comprehensive strategies and list out the ten priority traits to hasten the breeding programmes (Mohd. Din *et al.*, 2005). In the past decades, most of the breeding programmes placed high priority on the main thrusts and less emphasis on agronomic perspectives even when several studies had demonstrated that there were genotype × fertilizer interactions on bunch yield, oil, and kernel production in oil palm (Corley *et al.,* 1988; Corley *et al.,* 1995; Lee & Donough, 1993; Kushairi *et al.,* 1998).

Most of the oil palm nutritional research works carried out in the last 30 years on palms is mostly derived from D×P AVROS planting materials. These provided a reference for optimal leaf nutrient concentrations as a benchmark to the oil palm industry to formulate their fertilizer requirements (Fairhurst *et al.,* 2005; Goh & Hardter, 2003). Therefore, understanding the behaviour of each type of leaf nutrient concentration of the particular planting material in relation to each growing environment is crucial to provide site specific fertilizer recommendation. The costs of fertilizers had increased over the years from USD 110-150 ha^{-1} in 1990s to more than USD 700 ha^{-1} in 2008 (Tang *et al.,* 1999), mainly due to the increase in fertilizer prices, particularly K fertilizer and the higher fertilizer rates used. Extensive and concurrent study showed that leaf nutrient concentrations in oil palm were affected by genotype, irrigation and terrain (Lee *et al.,* 2011). This experiment was carried out in irrigated and non-irrigated areas with different planting materials as variables which provide an opportunity to evaluate leaf nutrient concentrations in the selected planting materials over a four-year period (2004-2007). All planting materials evaluated showed significant differences in their leaf nutrient concentrations. The leaf K concentrations of Yangambi origins were predominately lower than the other origins. It is of interest to understand how these leaf cations, K, Ca and Mg express themselves and their partition over eight years (1-8 years-old planting). It is well established that the optimum activity of many key enzymes in plant metabolism, such as pyruvate kinase (Miller and Evans, 1957) and stomata opening (Thomas, 1970) depend on an optimal balance of total leaf cations (TLC) = Ca + Mg + K and other major nutrients, N and P in the plant. Therefore, understanding the cation partitioning over eight years of palm growth, relationship between leaf nutrient concentrations and oil yield components are the main focus discussed in this paper.

MATERIALS AND METHODS

This experiment was laid out in 1999 at the Tun Razak Centre for Agricultural Services, Jerantut, Pahang, Malaysia (3° 52' 55'' North, 102° 43' 41'' East) to evaluate leaf nutrient concentrations of selected oil palm planting materials for three stages i.e (i) 1-2 years after planting, (ii) 3-4 years after planting, and (iii) 5-8 years old planting (yielding phase). This region is moderately wet with a mean annual rainfall of about 1900 mm and with two moderately dry periods (January to March, and July to August), each lasting about 2-3 months plus a very wet monsoonal period from October to December (Foong & Lee, 2000). The flatbed method was deployed to irrigate the palms under undulating and terraced areas (Lee & Romzi, 2000).

Planting materials and planting density

A total of six oil palm planting materials of various origins, namely (i) AVROS-A122 clone, (ii) La Me-L110 clone, (iii) Yangambi-Y103 clone, (iv) NIFOR-N114 clone, and two D×P hybrids, (v) Yangambi-DQ8 (ML161 which represents the present commercial planting material) and (vi) Yangambi-SC3 were chosen in this study. The palms were planted on two terrains i.e. undulating ($2-5^0$ slope) and terraced area ($6-12^0$ slope). For the undulating area, palms were planted at 136 palms/ha and terraced area at 128 palms/ha.

Frond sampling and tissue analyses

For palm age between 1-2 years old, frond number 9 was collected. Frond number 17 was selected when the palm age was more than three years old. Ten leaflets from each side of the middle of the leaf were sampled. The middle third of the leaflets was sub-sampled for nutrient analysis. The leaflets were cleaned with a moist cloth and after removing the laminae from the leaflets; they were subsequently cut into pieces of about 2 cm lengths and placed in a labeled paper bag. They were then dried at 80^oC for four hours. The samples were then ground to pass through 1 mm sieve and kept in labeled plastic bags. The dried samples were analyzed in the laboratory for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), chlorine (Cl) and boron (B) following the methodologies set out in the Malaysian SIRIM (1980) Standards.

Bunch component analysis

In each study plot, a total of 35 batches of fresh fruit bunches (FFB) were harvested over the four year period and represented specific treatments of terrain, irrigation, and planting materials. For each type of planting material that were planted under irrigation and terrain, at least 280 bunches were harvested over the four year period. These bunches were weighed and taken to the laboratory for bunch analysis and the oil and kernel content of the fruits were determined as described by Blaak *et al.* (1963).

Data analysis

The experiment was laid out as a 2 × 2 × 6 factorial trial comprising two irrigation types, two terrain and six planting materials in a randomized complete block design (RCBD) with two replications. Due to limited ramets in some clones, unequal plot sizes were used. For data recordings, the inner core of replicate one with 16 palms (4 × 4) of the 6 × 6 palm plots and replicate two with 4 palms (2 × 2) of the 4 × 4 palm plots were used. Due to two replications for each treatment, the analysis used is to pool or average out and confine to effects of planting materials (n=8). For separation of means, TUKEY's HSD (honestly significantly different) test was carried out. All the statistical analyses were performed using the SAS package version 9.0 for Windows (2002).

RESULTS

Effect of planting materials on leaf nutrient concentrations

In general, all the planting materials demonstrated statistically significant differences ($p<0.05$) in all the leaf nutrient concentrations (*Table 1*). Clearly, the clonal material NIFOR-N114 showed consistent significantly higher concentrations of the major nutrients except for Mg and B as compared to the other planting materials. In contrast, clonal material AVROS-A122 appeared to have significantly higher values of leaf N, K, Ca, Mg, S and Cl. Clonal Yangambi-Y103 showed statistically significant differences in leaf N, K and S. It is noted that DxP Yangambi palm (DQ 8) showed significantly 19% higher leaf Mg concentration, 18% higher leaf Ca concentration, 9% higher leaf P concentration, 9% higher leaf S concentration and 7% higher leaf N concentration as compared to clonal Yangambi-Y103 palm. Other leaf nutrient concentrations such as B, P, Ca and Mg were not significantly affected in this study.

Even though AVROS-122 and D×P Yangambi-DQ8 showed higher leaf Ca concentration (> 0.9%), they could still maintain reasonably high leaf Mg concentrations of > 2.50%. Nevertheless, the clonal material La Me-L110 showed the highest leaf P and K concentrations but depressed leaf Mg concentration (0.169%).

Leaf K concentration for D×P Yangambi DQ8 consistently showed a lower value by almost 15-20% as compared to clonal material AVROS-A122 in all the growing conditions (*Figures 1a-d*). It is also apparent that most of the leaf K concentrations of D×P Yangambi-DQ8 were much lower than the current leaf optimal level (at 1.0%) as compared to the AVORS material (A122).

Results from this study indicated that high yielding palms (Yangambi-Y103, AVROS-A122 and Yangambi-DQ8) were capable of retaining reasonable moderate to high leaf nutrient concentrations. In contrast, for poor yielding palms (Yangambi-SC3 and NIFOR-N144), almost all the leaf nutrient concentrations were significantly higher except for Ca in Yangambi-SC3 and leaf Mg in NIFOR-N144.

Assessment trend of total leaf cations over 8 years

Results from eight years of assessment revealed that TLC range from 80-100% (*Table 2*). For leaf Mg, it only contributed about 21-24% of individual cation over TLC. For instant, leaf K, although it was at high portion at almost 40% of individual cation over TLC for 1-2 years after planting (YAP), it was subsequently reduced to about 32% of individual cation over TLC. On the other hand, the leaf Ca appeared to be partitioned at about 36% TLC for the 1-2 YAP but at higher partition to almost 50% TLC for the rest of assessment period (3-8 YAP). It appeared that high yielding palms (Yangambi-Y103, AVROS-A122 and Yangambi-DQ8), consistently recorded higher TLC throughout this study except for Yangambi-Y103 at 5-8 YAP.

Yield component for fresh fruit bunch, oil and kernel yield

There were no significant effects on FFB production for all the tested planting materials (*Table 3*). The planting materials showed significantly similar FFB production but oil yield parameters were significantly different between them. The oil yield and total economic product (TEP) performances of AVROS-A122, Yangambi-Y103, Yangambi-DQ8 and La Me-L110 were superior in comparison to NIFOR-N114 and the lowest yielder is Yangambi-SC3.

Correlation between leaf nutrient concentration and oil yield components

There was no statistical significant relationship between FFB yield (t/ha) and all leaf nutrient concentrations (*Table 4*). Oil to bunch (O/B) ratio was positively and highly correlated with leaf Ca (r=0.65**), total leaf cations (TLC) (r=0.49**), leaf Mg (r=0.26*), leaf Cl (r=0.22*) and leaf S (r=0.19*). Kernel to bunch (K/B) ratio was correlated with leaf K (r=0.44**), leaf N (r=0.28**), leaf Mg (r=0.28**), leaf Cl (r=0.30**) and leaf S (r=0.21*). Overall, leaf Ca had a strong correlation with O/B ratio, oil yield and also total economic product (TEP) (*Figure 2a-c*).

DISCUSSIONS

An early study indicated that FFB production was significantly different between different planting materials (Lee *et al.*, 2005). In addition, the oil to bunch ratio (O/B) of the elite planting materials was generally higher than the standard control (Yangambi D×P, SC3), resulting in higher oil yield of 10-13.5% and total economic product of 5.2-8.0%. Although this study showed that there was no significant difference in FFB production between the different planting materials but a highly significant difference in oil yield was found between them. In contrast, the oil yield of clonal materials, such as AVROS-A122, Yangambi-Y103, and La Me-L110, were comparable to D×P Yangambi-DQ8; all of which were capable of producing 8.4 tonnes or more of total economic product (TEP).

With current high yielding palms, some research workers have proposed the use of additional N and K fertilizers to sustain good growth and yield (Zin, 1996). Consequently, an additional N (489 kg N/ha or equivalent to 1.7 kg ammonium sulphate/palm/year, an increase of 34.9%) and potassium (627 kg K/ha or equivalent to 0.93 kg muriate of potash/palm/year, an increase of 29.4%) are proposed.

A strong clone-environment interaction was seen based on the results of the first Bakasawit clonal palm programme trials (Corley *et al*., 1988; Corley *et al.*, 1995; Lee & Donough, 1993). Besides, recent studies showed that some clonal palms (Donough *et al*., 1996; Goh *et al.*, 2009) and hybrid (Jacquemard *et al.*, 2009) needed low N and K fertilizers inputs. Jacquemard *et al.* (2009) also claimed that some elite planting materials such as (DA5D×DAD3D)×LM311P required low fertilizer input in order to produce 7.7 tonnes CPO/ha. This implies that fertilizer inputs may have to be clone-specific and this fact must be taken into account as newer high yielding oil palm clones are planted commercially in the foreseeable future.

In Malaysia, leaf analysis results are widely employed for fertilizer recommendations in oil palm agronomy (Goh & Hardter, 2003). The present study indicated that D×P Yangambi-DQ 8 (one of the progenies related to Yangambi ML161 crosses) consistently showed 15-20% lower leaf K than the clonal materials of AVROS-A122 in all the growing conditions despite similar fertilizer regimes being given for the entire planting system. The plausible reason could be due to the clonal materials AVROS-122 and D×P Yangambi-DQ8 having higher leaf Ca concentration (> 0.9%) and higher leaf Mg concentration (> 2.50%) which limit the K absorption (Goh & Hardter, 2003; Foster, 2003). As such, leaf K status for D×P Yangambi (DQ8) at 0.99% was low. A similar observation was reported by Jacquemard *et al.* (2009) for progeny origin from Dabou (DA115D and its selfing derivatives) which were high in leaf N, Ca and Cl but low in K.

This study clearly demonstrated that all the planting materials were significantly different in all the leaf nutrient concentrations. High yielding planting materials (Yangambi-Y103, AVROS-A122, and Yangambi-DQ8), had moderate to high leaf nutrient concentrations and consistently recorded higher TLC throughout this study. In contrast, the poorer yielding palms (Yangambi-SC3 and NIFOR-N144) had significantly higher nutrient status except for Ca, when compared to the high yielding materials. Yangambi-SC3 had the lowest Ca status and TLC value among the planting materials studied. In terms of percentage individual cation partitioning, leaf Ca of Yangambi SC3 recorded the lowest value for three periods of assessment. The rest of the planting materials were able to take up higher and represent more than 50% of partition in TLC. The correlation studies between leaf nutrient concentrations and oil yield components showed that leaf Ca was most strongly correlated to oil to bunch (O/B) ratio, oil yield and total economic product (TEP). The FFB yield is well known to be correlated with leaf nutrient status (Lee *et al*., 2008) and to produce high yield of 30 tonne FFB/ha. Thus maintaining a correct combination of leaf N and K is required. Other workers have also reported a higher total nutrient requirement in clonal palms with a higher yield potential (32.3 t/ha) when compared to D×P palm with a yield of 19.4 t/ha (Woo *et al*., 1994). Over a 6-year period after field planting, K requirement by the clonal palm was 1,547 kg/ha; an increase of 11% than the requirement of D×P palm. Potassium use efficiency in the clonal palm also increased by 51% when compared to that in D×P palm at 13.90 kg oil/kg K. Therefore, besides selecting higher productivity of palms for efficient oil production, the leaf nutrient concentrations, particularly Ca, deserve further investigation.

CONCLUSION

The major finding of this study showed that leaf K concentrations for D×P Yangambi-DQ8 were consistently 15-20% lower than AVROS-A122 in all the growing conditions. In addition, the planting materials which produced high oil yield and reached more than 8.7 tonnes of total economic yield, *viz.* Yangambi-DQ8, Yangambi-Y103 and AVROS-A122 also had low K leaf status especially Yangambi origins but consistently recorded higher TLC values throughout this study. The current generalized leaf nutrient critical levels based on inland and coastal areas should be revised and the approach to apply fertilizers should be site and planting material specific in order to produce high FFB yields sustainably.

ACKNOWLEDGEMENTS

The authors wish to thank the Senior Executive Director Group R & D / CEO of FELDA Agricultural Services Sdn. Bhd., Mr. S. Palaniappan for permission to publish this paper. The authors also wish to acknowledge the contributions from FASSB research colleagues particularly Mr. Foong Sang Foo (former Head of Agronomy Unit), who initiated the project in collaboration with the Breeding and Tissue Culture Unit, Dr. Maheran Abu Bakar who provided the clonal materials and the staff of the Agronomy Unit, who ensured the success of this project.

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Table 1: Effect of planting materials on leaf nutrient concentration

	n	N	P	K	Ca	Mg	S	Cl	B
					(%)				**(mg/kg)**
Planting Material		**All values are averaged over 2 terrains and 2 irrigation conditions**							
FELDA Clone									
Yangambi-Y103	8	2.49±0.034[c]	0.159±0.004[d]	0.96±0.068[c]	0.80±0.117[c]	0.21±0.043[b]	0.140±0.002[c]	0.70±0.037[c]	16.2±2.535[ab]
NIFOR-N114	8	2.80±0.038[a]	0.180±0.003[a]	1.03±0.063[bc]	0.89±0.064[bc]	0.17±0.022[c]	0.159±0.003[a]	0.70±0.026[c]	16.4±2.281[a]
La Me-L110	8	2.81±0.043[a]	0.173±0.004[b]	1.20±0.084[a]	1.02±0.077[a]	0.25±0.018[a]	0.159±0.003[a]	0.76±0.030[a]	15.2±0.751[ab]
AVROS-A122	8	2.80±0.093[a]	0.166±0.007[bc]	1.15±0.107[a]	0.97±0.067[ab]	0.26±0.021[a]	0.160±0.003[a]	0.76±0.032[ab]	15.7±1.842[ab]
FELDA DxP									
Yangambi-DQ8	8	2.69±0.061[b]	0.165±0.002[cd]	0.99±0.089[bc]	0.98±0.047[ab]	0.26±0.010[a]	0.153±0.004[b]	0.72±0.018[abc]	17.3±1.853[a]
Yangambi-SC3	8	2.79±0.055[a]	0.170±0.003[bc]	1.10±0.080[ab]	0.68±0.029[d]	0.19±0.028[bc]	0.159±0.003[a]	0.72±0.033[bc]	13.7±1.283[b]
ANOVA RESULTS		**	**	**	**	*	*	**	**
C.V (%)		2	2	7	7	10	3	11	2

Note: values with the same alphabets are not significantly different from each other
n = number of replicate
* $P<0.05$, ** $P < 0.01$, n.s., $P>0.05$ not significant.

Table 2: Total leaf cation (TLC) and their distribution 1-8 years old palm

Palm age	Leaf Concentration (%)						% Individual Cation (m.e)								% Distribution of Individual Cation Over Total Cation			
	K		Ca		Mg		K		Ca		Mg		total		K	Ca	Mg	total
1-2 Years Old																		
FELDA Clone Nifor (N114)	1.36	ab	0.61	a	0.29	a	34.7	ab	30.6	a	23.4	a	88.7	b	39.1	34.5	26.4	100.0
FELDA Clone La Me (L110)	1.27	b	0.62	a	0.22	b	32.4	b	31.1	a	17.9	b	81.4	c	39.8	38.2	22.0	100.0
FELDA Clone Avros (A122)	1.46	a	0.69	a	0.27	a	37.4	a	34.2	a	22.1	a	93.8	a	39.9	36.5	23.6	100.0
FELDA Clone Yangambi (Y103)	1.45	a	0.67	a	0.28	a	37.2	a	33.3	a	23.2	a	93.7	a	39.7	35.5	24.8	100.0
FELDA DxP (DQ8)	1.41	a	0.68	a	0.30	a	35.9	a	34.1	a	24.4	a	94.5	a	38.0	36.1	25.8	100.0
FELDA DxP (SC3)	1.38	ab	0.50	b	0.24	b	35.2	ab	25.1	b	19.7	b	80.0	c	44.0	31.4	24.6	100.0
Mean	1.39		0.63		0.27		35.5		31.4		21.8		88.7		40.07	35.39	24.53	100.0
C.V (%)	6		12		7		6		12		7		4					
3-4 Years Old																		
FELDA Clone Nifor (N114)	1.02	c	0.84	bc	0.28	ab	26.1	c	42.1	bc	23.4	ab	91.5	b	28.5	46.0	25.5	100.0
FELDA Clone La Me (L110)	1.04	bc	0.82	cd	0.22	d	26.7	bc	40.9	cd	18.1	d	85.7	c	31.2	47.7	21.1	100.0
FELDA Clone Avros (A122)	1.20	a	0.98	a	0.26	bc	30.7	a	49.0	a	21.1	bc	100.7	a	30.5	48.6	20.9	100.0
FELDA Clone Yangambi (Y103)	1.18	a	0.93	abc	0.26	b	30.3	a	46.2	abc	21.3	b	97.7	a	31.0	47.2	21.8	100.0
FELDA DxP (DQ8)	1.03	bc	0.96	ab	0.30	a	26.4	bc	47.7	ab	24.4	a	98.5	a	26.8	48.4	24.8	100.0
FELDA DxP (SC3)	1.13	ab	0.71	d	0.22	cd	28.9	ab	35.6	d	18.4	cd	82.9	c	34.8	42.9	22.2	100.0
Mean	1.10		0.87		0.26		28.2		43.6		21.1		92.8		30.5	46.8	22.7	100.0
C.V (%)	6		9		9		6		9		9		3					
5-8 Years Old																		
FELDA Clone Nifor (N114)	1.03	bc	0.88	bc	0.17	c	26.2	bc	44.0	bc	13.9	c	84.2	c	31.2	52.3	16.5	100.0
FELDA Clone La Me (L110)	1.20	a	1.02	a	0.25	a	30.8	a	50.7	a	20.7	a	102.2	a	30.1	49.6	20.3	100.0
FELDA Clone Avros (A122)	1.15	a	0.97	ab	0.26	a	29.3	a	48.3	ab	21.2	a	98.8	ab	29.6	48.9	21.5	100.0
FELDA Clone Yangambi (Y103)	0.96	c	0.80	c	0.21	b	24.5	c	39.7	c	17.7	b	81.9	cd	29.9	48.5	21.6	100.0
FELDA DxP (DQ8)	0.99	bc	0.97	ab	0.26	a	25.2	c	48.5	ab	21.5	a	95.2	b	26.5	50.9	22.6	100.0
FELDA DxP (SC3)	1.10	ab	0.68	d	0.19	bc	28.2	ab	33.8	d	15.4	bc	77.4	d	36.4	43.7	19.9	100.0
Mean	1.07		0.89		0.22		27.4		44.2		18.4		90.0		30.6	49.0	20.4	100.0
C.V (%)	7		7		10		7		7		10		4					

Note: values with the same alphabets are not significantly different from each other.

Table 3: Summary of FFB Yield, Palm Oil and Kernels Oil Yield (2004-2007)

Treatment	Mean Oil Yield Product (t/ha)					
	FFB (t/ha)	Oil Yield		Kernel Oil Yield		TEP (t/ha)
		O/B (%)	(t/ha)	K/B (%)	(t/ha)	
Planting Material	**All values are averaged over 2 terrains and 2 irrigated conditions**					
FELDA Clone						
Yangambi-Y103	24.62[a]	33.77[a]	8.31[a]	5.56[a]	1.37[a]	9.14[a]
NIFOR-N114	24.24[a]	29.06[b]	7.04[b]	2.61[c]	0.63[c]	7.42[b]
La Me-L110	24.44[a]	32.67[a]	7.98[a]	2.80[c]	0.68[c]	8.40[a]
AVROS-A122	24.73[a]	33.96[a]	8.40[a]	5.52[a]	1.36[a]	9.22[a]
FELDA DxP						
Yangambi-DQ8	24.39[a]	33.49[a]	8.17[a]	4.05[b]	0.99[b]	8.76[a]
Yangmbi-SC3	23.68[a]	28.10[b]	6.65[b]	5.91[a]	1.40[a]	7.49[b]
Trial Mean	**24.35**	**31.84**	**7.76**	**4.41**	**1.07**	**8.40**
C.V (%)	8	3	8	9	11	9

Note: values with the same alphabets are not significantly different from each other
O/B = Oil to bunch; K/B = Kernel to bunch
Oil Yield = O/B (%) x Mean FFB Yield (2004-2007)
Kernel Yield = K/B (%) x Mean FFB Yield (2004-2007)
TEP (Total Economic Product) = Oil Yield + (0.6) Kernel Yield
* P<0.05, ** P < 0.01, n.s., P>0.05 not significant.

Table 4: Correlation between leaf nutrient concentrations and oil yield components

	P		K		Ca		Mg		Cl		S		B		O/B		K/B		FFB Yield		Oil Yield		Kernel Yield		TEP	
N	0.49	**	0.41	**	0.10	ns	0.00	ns	0.20	*	0.95	**	0.03	ns	0.17	*	0.28	**	0.01	ns	0.04	ns	0.24	*	0.08	ns
P			0.09	ns	0.04	ns	0.07	ns	0.01	ns	0.43	**	0.02	ns	0.08	ns	0.01	ns	0.00	ns	0.03	ns	0.01	ns	0.02	ns
K					0.12	ns	0.22	*	0.42	**	0.41	**	0.14	ns	0.06	ns	0.44	**	0.09	ns	0.00	ns	0.32	**	0.00	ns
Ca							0.31	*	0.34	**	0.13	ns	0.03	ns	0.65	**	0.00	ns	0.00	ns	0.22	*	0.00	ns	0.20	**
Mg									0.36	**	0.00	ns	0.02	ns	0.22	*	0.11	ns	0.00	ns	0.08	ns	0.11	ns	0.11	ns
Cl											0.23	*	0.04	ns	0.26	*	0.28	**	0.00	ns	0.08	ns	0.26	**	0.13	ns
S													0.02	ns	0.19	*	0.30	**	0.00	ns	0.05	ns	0.28	**	0.09	ns
B															0.10	ns	0.21	*	0.12	ns	0.16	ns	0.11	ns	0.10	ns
O/B																	0.01	ns	0.08	ns	0.61	**	0.03	ns	0.58	**
K/B																			0.00	ns	0.00	ns	0.91	**	0.05	ns
FFB Yield																					0.67	ns	0.07	ns	0.66	**
Oil Yield																							0.08	ns	0.97	**
Kernel Yield																									0.21	*

** * and ns are significant at P< 0.01, P<0.05 and non significant, respectively
O/B = oil to bunch
K/B = kernel to bunch
TEP = total economic product

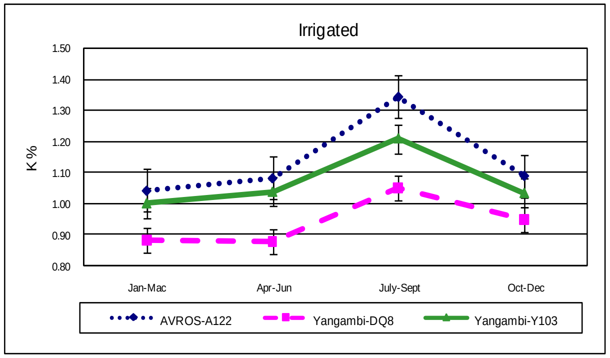

Figure 1a: Leaf K status for irrigated palms
(all values averaged over 2 terrain conditions)

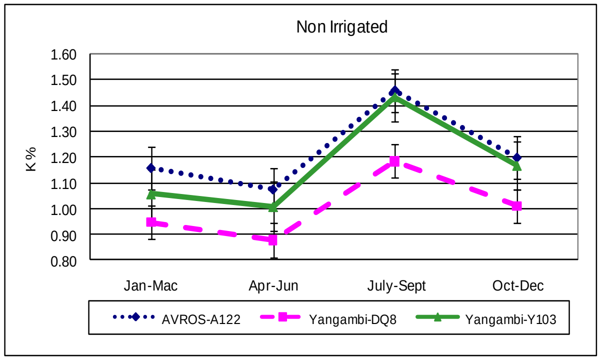

Figure 1b: Leaf K status for non-irrigated palms
(all values averaged over 2 terrain conditions)

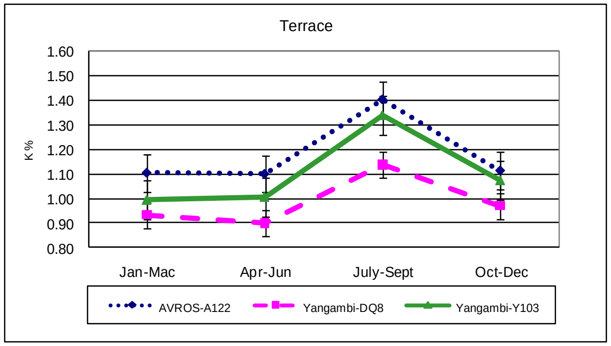

Figure 1c: Leaf K status under terraced area
(all values averaged over 2 irrigation conditions)

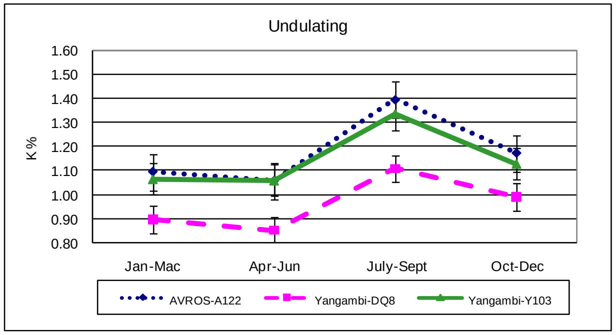

Figure 1d: Leaf K status under undulating area
(all values averaged over 2 irrigation conditions)

Figure 1: Leaf K concentration for clonal material AVROS-A122, Yangambi-Y103 and DxP Yangambi-DQ8

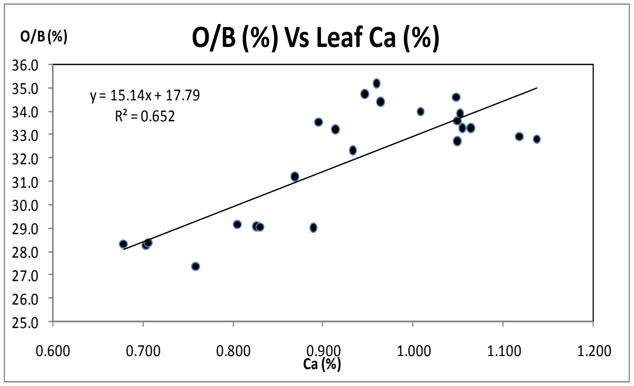

Figure 2a: Relationship between O/B against leaf Ca

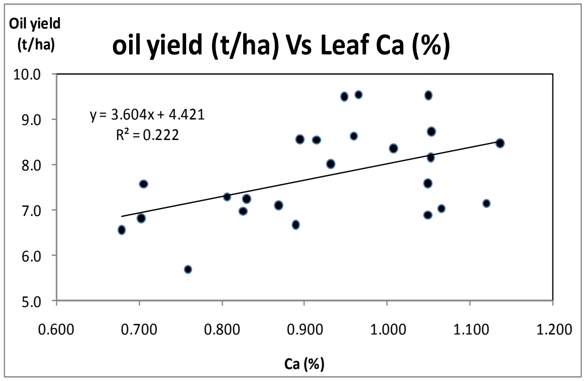

Figure 2b: Relationship between oil yield against leaf Ca

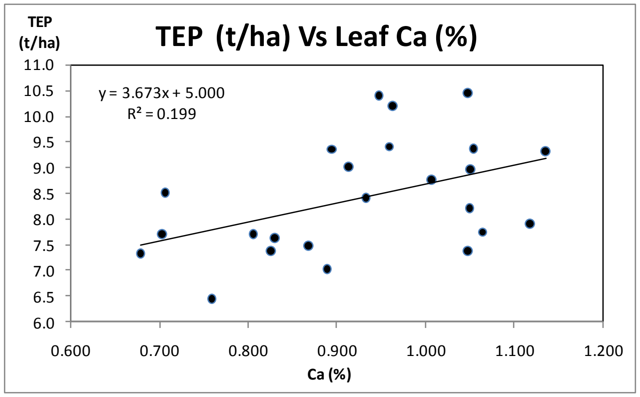

Figure 2c: Relationship between total economic product (TEP) against leaf Ca

Figure 2: Relationship between leaf Ca against oil to bunch (O/B), oil yield and total economic product (TEP)