Journal of Oil Palm & The Environment 2011, 2:38-47 doi:10.5366/jope.2011.05

Leaf Nutrient Concentrations in Oil Palm as Affected by Genotypes, Irrigation and Terrain

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Abstract

Four clonal oil palm materials namely AVROS, Yangambi, La Me and NIFOR and two DxP hybrid Yangambi, grown on terraced and unterraced fields were subjected to irrigated and non-irrigated conditions. There were significant differences in all leaf nutrient concentrations for all the planting materials for both terrain and irrigation conditions. For non-irrigated palms, most of the leaf nutrients were higher than the irrigated palms, especially K and Mg concentrations. Most of the leaf nutrient concentrations in palms grown on undulating area were also high, especially for leaf Mg and K concentrations. Leaf K concentration for DxP 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. In view of future high current fertilizer cost, selecting oil palm genotypes that are able to produce good oil yields on low fertilizer inputs and giving consistent leaf nutrition need to be given consideration.

Keywords

Leaf nutrients, irrigation, terrain, oil palm, clones

JOPE 2011, 2:38-47

1. Introduction

Most of the oil palm nutritional research works carried out in the 1960s to 1990s were on palms derived from DxP 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^{1, 2}. Fertilizer is the single most important and costly manageable input in oil palm cultivation. 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 2008³, mainly due to the increase in fertilizer prices, particularly K fertilizer and higher fertilizer rates used.

The roles of biotic factors on oil palm nutrition are expected to become more prominent as we breed for true to type inbred hybrids with more uniform genetic make-up on a commercial scale. Recent work revealed that some clonal palms^{4,5} and hybrids⁶ were responsive to low fertilizer inputs and still produced high yields.

The oil palm leaf nutrient concentrations are affected by many factors such as soil types, available water, yield level in the month preceding the leaf nutrient sampling, fertilizer application⁷, age of palms^{8, 9}, vegetative growth¹⁰ and seasonal factors, including rainfall¹¹.

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Published: 23 July 2011

Received: 10 May 2011

Accepted: 26 May 2011

This article is available from: <http://www.jope.com.my>

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The current status of leaf nutrient concentrations will determine the status of palm health and lead to appropriate rate of fertilizers to be applied.

Large oil palm yield response in the drier environment with irrigation was reported both in Malaysia and Thailand^{12, 13}. In view of this, an experiment on irrigation and planting materials was carried out at two different topographical sites, i.e. undulating (2-5° slopes) and terraced area (6-12° slope). This provided an opportunity to evaluate leaf nutrient concentrations in the selected planting materials over four years (2004-2007) in relation to (i) topography of planting area (ii) irrigation and (iii) planting materials on oil palm yield performance. The relationship between leaf nutrient concentrations and oil yield components were also studied.

2. Methodology

2.1. Trial site and irrigation method

An experiment was laid out in 1999 at the Tun Razak Centre for Agricultural Services in Jerantut, Pahang, Malaysia (3° 52' 55" North, 102° 43' 41" East) to evaluate the selected planting materials under irrigated and non-irrigated conditions. 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 December¹⁴.

The flatbed system was used in both the undulating and terraced areas. Flatbeds were constructed in alternate palm rows for the undulating area. For the terraced area, the flatbeds were constructed in the inter-terraces two years after planting. During the first two years of planting, the back-drop of the terrace was used to channel water to the palms. Flatbed size was 1.5 m wide x 0.5 m deep. The connecting drain between two adjacent flatbeds along the same inter-row area was 0.2 m wide x 0.2 m deep x 1.5 m long. Details of

flatbed specifications were reported by Lee and Romzi¹⁵.

Irrigation was carried out to meet the evapotranspiration demand of 5.0 to 6.0 mm/day. Overall, the frequency of irrigation was about once in every 5-7 days. The average amount of water delivered per irrigation was about 2,000 liters per palm or about 285 liters per day.

2.2. Planting materials and planting density

Six planting materials of various origins, namely, (i) AVROS-A122 (ii) La Me-L110 (iii) Yangambi-Y103 (iv) NIFOR-N114 and two DxP hybrids (v) Yangambi-DQ8 (ML161 which represents the present commercial planting material) and (vi) Yangambi-SC3 were studied. The palms were planted on two terrains i.e. undulating and terraced area. For the undulating area, palms were planted at 136 palms/ha and terraced area at 128 palms/ha.

2.3. Frond sampling and tissue analyses

Frond number 17 from the treatment palm was used to determine palm nutrient status from 2004, i.e. when the palm was five 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 cut into pieces of about 2 cm length and placed in a labeled paper bag. They were then dried at 80°C 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 for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), chlorine (Cl) and boron (B) following the methodology set out in the Malaysian SIRIM Standards 16.

2.4. Fertilizers applied

The fertilizers applied are shown in Table 1.

Table 1: Fertilizer types and amounts applied

Year	Nutrient Applied (kg/palm/year)						
	N	P	K	Mg	Ca	S	Cl
2004	0.630	0.259	1.494	0.204	0.576	0.995	1.428
2005	0.840	0.296	1.992	0.285	0.658	1.345	1.904
2006	0.893	0.296	2.117	0.244	0.658	1.350	2.023
2007	0.945	0.334	1.828	0.244	0.740	1.410	1.747

Source of fertilizer: N= ammonium sulphate, P= Christmas Island phosphate rock, K= muriate of potash and Mg= kieserite

2.5. Bunch components analysis

In each plot, a total of 35 batches of fruit bunches were harvested over the four year period and represented specific treatments of terrain, irrigation and planting materials. For each type of planting material planted under irrigation and terrain, at least 280 bunches were harvested over the four year period. The bunches were weighed and taken to the laboratory for bunch analysis and the oil and kernel contents of the fruits were determined by using the methods of Blaak et al.¹⁷.

2.6. Data analysis

The experiment was laid out as a 2x2x6 factorial trial comprising of 2 irrigation types, 2 terrain types and 6 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 x 4) of the 6 x 6 palm plots and replicate two with 4 palms (2 x 2) of the 4 x 4 palm plots were used. A two-way analysis of variance (ANOVA) was used to analyze the experimental data. For separation of means, TUKEY's HSD (honestly significantly different) test was carried out. All the analyses were made using the SAS package version 9.0 for Windows¹⁸.

3. Results

3.1. Effect of irrigation on leaf nutrient concentrations

Leaf nutrient concentrations for N, P, K and Mg were significantly ($p \leq 0.05$) reduced under irrigated conditions; leaf Mg by 9%, K 8% and P 2% compared to the non-irrigated palms. There were no significant differences in leaf nutrient concentrations for S, B and Cl under irrigated conditions (Tables 2 and 3). The irrigated palms showed 6% higher Ca content (Table 3) while the other nutrients in the leaves were significantly lower by 1-4%.

3.2. Effect of planting materials on leaf nutrient concentrations

All the planting materials showed significant differences in all the leaf nutrient concentrations (Table 2). The clonal material NIFOR-N114 showed significantly lower concentrations of all the nutrients except for Mg and B when compared to the other planting materials. In contrast, clonal material AVROS-A122 and Yangambi-Y103 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. DxP Yangambi palm (DQ 8) showed 16% significantly lower leaf K concentration, 5% lower S concentration and 4% lower N when compared to clonal Yangambi-Y103 palm. Leaf B concentration was found to be 9% higher. Other leaf nutrient concentrations like P, Ca and Mg were not significantly affected.

Despite AVROS-122, Yangambi-Y103 and DxP Yangambi-DQ8 showing higher leaf Ca concentrations ($> 0.9\%$), they could still maintain reasonably high leaf Mg values of $> 2.50\%$. The clonal material of La Me-L110 showed the highest leaf P and K concentrations but depressed leaf Mg concentration (0.169%).

Leaf K concentration for DxP Yangambi DQ8 was 15-20% lower when compared to AVROS-A122 and Yangambi-Y103 in all the growing conditions. In fact, the leaf K concentration of DxP Yangambi-DQ8 was much lower than the optimal leaf K level of 1.0%.

3.3. Leaf nutrient interactions between irrigation, planting materials and terrain

Different planting materials showed highly significant ($p < 0.01$) differences in all the plant nutrients evaluated (Table 2). Irrigation had a strong interaction on major plant nutrients (N, P, K and Mg) and not for others. In contrast, terrain had a strong interaction on P, Mg, Cl, B and S. There was no interaction between irrigation, terrain and planting materials for all the plant nutrients studied except for planting material x terrain for leaf Ca at $p < 0.05$.

3.4. Fresh Fruit Bunch (FFB) yield

The FFB yields on irrigated plots were significantly higher than the non-irrigated plots (Table 4). The irrigated plots yielded 25.62 tonnes/ha (t/ha) which was higher by 11% or 2.54 t/ha when compared to non-irrigated plots at 23.08 t/ha.

The FFB yield of the undulating area (25.35 t/ha) was significantly higher than the terraced area at 23.34 t/ha; an increase of 8.6% or 2.01 t/ha in the former area. There were no significant effects on FFB production for all the planting materials tested. No interactions were detected amongst terrain, irrigation and planting materials.

Table 2: Effect of irrigation, terrain and planting materials on leaf nutrient concentrations and their ANOVA results

	n	N	P	K	Ca	Mg	S	Cl	B
		(%)							(mg/kg)
Irrigation		All values are averaged over 6 planting materials and 2 terrain conditions							
Irrigated (IR)	24	2.71±0.122 ^b	0.167±0.007 ^b	1.03±0.111 ^b	0.87±0.129 ^a	0.21±0.045 ^b	0.153±0.008 ^a	0.73±0.037 ^a	15.8±1.675 ^a
Non-irrigated (NIR)	24	2.75±0.133 ^a	0.170±0.008 ^a	1.11±0.111 ^a	0.91±0.146 ^a	0.23±0.042 ^a	0.156±0.007 ^a	0.73±0.041 ^a	15.5±2.463 ^a
IR/NIR (%)		99	98	92	96	91	98	100	102
Terrain		All values are averaged over 6 planting materials and 2 irrigation conditions							
Undulating (U)	24	2.72±0.134 ^a	0.170±0.008 ^a	1.06±0.120 ^a	0.88±0.140 ^a	0.23±0.048 ^a	0.154±0.008 ^a	0.72±0.042 ^b	16.5±1.616 ^b
Terraced (T)	24	2.74±0.123 ^a	0.167±0.007 ^b	1.08±0.118 ^a	0.90±0.136 ^a	0.22±0.040 ^b	0.156±0.007 ^b	0.74±0.033 ^a	14.9±2.226 ^a
U/T (%)		99	102	99	97	107	99	97	111
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-N144	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							
Irrigation (IR)		*	*	**	n.s.	**	n.s.	n.s.	n.s.
Terrain (TR)		n.s.	*	n.s.	n.s.	*	*	*	**
Planting Material (PM)		**	**	**	**	*	*	**	**
Interaction (IR x TR)		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Interaction (IR x PM)		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Interaction (PM x TR)		n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.
C.V (%)		2	3	7	7	9	2	4	11

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

n = number of replicates * P<0.05, ** P < 0.01, n.s. not significant.

Degrees of freedom are: Irrigation 1, Planting material 5, Terrain 1, Irrigation x Planting material interaction 5, Irrigation x Terrain interaction 1, Planting material x Terrain interaction 5

Table 3: Effect of irrigation, terrain and planting materials on leaf nutrient contents and their ANOVA results

	n	N	P	K	Ca	Mg	S	Cl	B
		gm /frond							x10 ⁻⁶ gm/frond
<u>Irrigation</u>		All values are averaged over 6 planting materials and 2 terrain conditions							
Irrigated (IR)	24	73.14±7.94 ^b	4.500±0.56 ^b	27.60±2.97 ^b	24.81±2.86 ^a	5.73±1.13 ^b	4.120±1.94 ^b	19.58±0.43 ^a	430.2±73.21 ^a
Non-irrigated (NIR)	24	76.16±10.17 ^a	4.740±0.75 ^a	30.69±3.40 ^a	23.32±3.80 ^b	6.40±0.96 ^a	4.320±2.25 ^a	20.11±0.59 ^a	434.2±97.00 ^a
IR/NIR (%)		96	95	90	106	90	95	97	99
<u>Terrain</u>		All values are averaged over 6 planting materials and 2 irrigation conditions							
Undulating (U)	24	75.08±9.71 ^a	4.71±0.69 ^a	29.23±3.52 ^a	23.99±3.70 ^a	6.32±1.10 ^a	4.250±2.18 ^a	19.81±0.57 ^a	459.1±81.89 ^a
Terraced (T)	24	74.21±8.75 ^a	4.54±0.64 ^a	29.06±3.60 ^a	24.14±3.17 ^a	5.81±1.05 ^b	4.190±2.06 ^a	19.89±0.48 ^a	405.3±81.72 ^b
U/T (%)		101	104	101	99	109	101	100	113
<u>Planting Material</u>		All values are averaged over 2 terrains and 2 irrigation conditions							
<u>FELDA Clone</u>									
Yangambi-Y103	8	62.71±3.76 ^c	3.75±0.25 ^c	25.66±2.08 ^d	21.64±2.36 ^{bc}	5.82±1.18 ^{bc}	3.57±0.20 ^c	17.08±1.02 ^c	356.5±66.22 ^c
NIFOR-N144	8	78.42±3.65 ^{ab}	5.01±0.32 ^{ab}	30.24±3.03 ^{abc}	25.05±2.19 ^a	6.78±0.89 ^{ab}	4.42±0.29 ^{ab}	22.03±0.90 ^a	352.4±76.72 ^c
La Me-L110	8	84.50±4.03 ^a	5.46±0.29 ^a	31.03±3.51 ^{abc}	26.94±2.52 ^a	5.11±0.66 ^c	4.77±0.24 ^a	21.22±1.21 ^{ab}	509.5±24.95 ^a
AVROS-A122	8	66.17±5.16 ^c	4.02±0.32 ^c	28.31±2.87 ^{bcd}	23.94±2.44 ^{ab}	5.94±0.58 ^{bc}	3.75±0.29 ^c	17.93±1.14 ^c	495.9±43.85 ^a
<u>FELDA DxP</u>									
Yangambi-DQ8	8	74.35±4.04 ^b	4.56±0.24 ^b	27.32±2.51 ^{cd}	27.01±2.18 ^a	7.28±0.49 ^a	4.19±0.23 ^b	19.99±1.09 ^b	477.5±56.27 ^{ab}
Yangambi-SC3	8	81.76±6.77 ^a	4.94±0.47 ^a	32.29±2.81 ^a	19.83±1.77 ^c	5.49±1.03 ^c	4.63±0.45 ^a	20.85±1.42 ^{ab}	401.4±62.03 ^{bc}
		ANOVA RESULTS							
Irrigation (IR)		*	*	**	*	**	*	n.s.	ns
Terrain (TR)		n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.	**
Planting Material (PM)		**	**	**	**	**	**	*	**
Interaction (IR x TR)		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	ns
Interaction (IR x PM)		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	ns
Interaction (PM x TR)		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	ns
C.V (%)		6	7	8	9	11	7	6	12

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

n = number of replicates * P<0.05, ** P < 0.01, n.s. not significant

Degrees of freedom are: Irrigation 1, Planting material 5, Terrain 1, Irrigation x Planting material interaction 5, Irrigation x Terrain interaction 1, Planting material x Terrain interaction 5

Table 4: Summary of FFB Yield, Palm Oil and Kernel Oil Yields (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)	
Irrigation	All values are averaged over 6 planting materials and 2 terrain conditions					
Irrigated	25.62 ^a	32.20 ^a	8.25 ^a	4.43 ^a	1.13 ^a	8.93 ^a
Non-Irrigated	23.08 ^b	31.48 ^b	7.27 ^b	4.38 ^a	1.01 ^b	7.87 ^b
Extra with Irrigation (%)	11.0	2.3	13.6	1.0	12.2	13.4
Terrain	All values are averaged over 6 planting materials and 2 irrigated conditions					
Undulating	25.35 ^a	31.94 ^a	8.10 ^a	4.39 ^a	1.11 ^a	8.77 ^a
Terraced	23.34 ^b	31.34 ^a	7.32 ^b	4.36 ^a	1.02 ^b	7.93 ^b
Extra with Undulating (%)	8.6	1.9	10.7	0.6	9.3	10.6
Planting Material	All values are averaged over 2 terrains and 2 irrigated conditions					
<u>FELDA Clone</u>						
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
<u>FELDA DxP</u>						
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
	ANOVA Results					
Irrigation (IR)	**	*	**	ns	**	**
Terrain (TR)	**	ns	**	ns	**	**
Planting Material	ns	**	**	**	**	**
Interaction (IR x TR)	ns	ns	ns	ns	ns	ns
Interaction (IR x MR)	ns	ns	ns	ns	ns	ns
Interaction (PM x TR)	ns	ns	ns	ns	ns	ns

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 Oil Yield

* P<0.05, ** P < 0.01, n.s. not significant.

3.5. Oil and kernel yields

The irrigated plots showed significant differences in all the oil yield parameters except for kernel to bunch (K/B) ratio. Terrain had no significant effect on oil to bunch (O/B) and kernel to bunch (K/B) ratios but had highly significant effects on total oil yield, kernel yield and total economic product (TEP). There was no interaction between irrigation, terrain and planting

materials in all oil yield parameters. Irrigated palms out-yielded the non-irrigated palms by 13.6%, 12.2% and 13.4% in oil, kernel and TEP respectively. Palms planted on undulating topography appeared to have higher yield for oil, kernel and TEP than the terraced area by 10.7%, 9.3% and 10.6% respectively.

The planting materials had significantly similar FFB production but oil yield parameters were significantly

different between them. The oil yield and total economic product (TEP) performance of AVROS-A122, Yangambi-Y103, Yangambi-DQ8 and La Me-L110 were superior to NIFOR-N114 and the lowest yielder was Yangambi-SC3.

4. Discussions

4.1. Influence of irrigation and terrain

Non-irrigated palms had higher leaf nutrient concentrations. Leaf K and Mg for these palms were almost 10% higher than the irrigated palms. On the contrary, irrigated palms yielded 11% more than non-irrigated palms. The high yields would demand higher plant nutrients to support good growth and yield. The larger nutrient drainage is reflected by lower foliar nutrient concentrations. In addition, leaching losses of soluble nutrients (K and Mg) were expected to be high with irrigation. Foong¹⁹ reported that K and Mg nutrients leaching losses amounted to almost 30-40% of total applied nutrients based on results obtained from irrigated single palm lysimeter studies. This explained the significantly large differences for these two mobile nutrients between irrigated and non-irrigated areas.

Leaf nutrient concentrations were higher, especially for leaf Mg and B, for palms grown in the undulating areas versus terraced areas. In fact, leaf Mg and B were almost 10% higher for palms in the undulating area. The lower nutrient concentrations for palms grown on terraces could be due to the smaller soil volume explored by the roots. Chang and Pupathy²⁰ showed that the volume of soil mass influenced the extent of nutrient and moisture uptake by the palms and resulted subsequently in variation in crop performance. Obviously, planting of palms on restructured top soil and practising moisture conservation measures would certainly improve crop performance. This is demonstrated by the use of innovative techniques such as large planting hole to retain soil moisture status and nutrient retention around the planting point whereby improved initial palm growth and higher early yields were obtained^{21, 22}.

The overall FFB yield and other oil components on irrigated plots were significant higher than the non-irrigated plots. In the drier region in Southern Thailand, Palat et al.¹³ reported that irrigation combined with a higher fertilizer rate produced an additional 10 tonnes per hectare per year or 54% more when compared to the non-irrigated plots with an average yield of 18.2 tonnes.

4.2. Implication of leaf analysis in relation to planting materials and its expected nutrient requirement

An early study showed that FFB production was significantly different between different planting materials²³. In addition, the oil to bunch ratio (O/B) of the elite planting materials was generally higher than the standard control (Yangambi DxP, SC3), resulting in 10-13.5% higher oil yield and 5.2-8.0% more total economic product. 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 between them was found. The oil yield of clonal materials such as AVROS-A122, Yangambi-Y103 and La Me-L110, were comparable to DxP Yangambi-DQ8; all of which were capable of producing more than 8.4 tonnes of total economic product (TEP).

With current high yielding palms, some research workers have proposed the use of additional nitrogen and potassium fertilizers to sustain good growth and yield²⁴. An additional nitrogen (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^{25, 26, 27}. Besides, recent studies showed that some clonal palms^{4, 5} and hybrids⁶ needed low N and K fertilizers inputs. Jacquemard et al.⁶ also claimed that some elite planting materials, such as (DA5D x DAD3D) x LM311P, required low fertilizer inputs 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 when newer high yielding oil palm clones are planted commercially in the future.

In Malaysia, leaf analysis results are widely employed for fertilizer recommendations in oil palm agronomy². The present study indicated that DxP 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 and Yangambi-Y103 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 of AVROS-122, Yangambi-Y103 and DxP Yangambi-DQ8 having higher leaf Ca concentrations (> 0.9%), and higher leaf Mg concentrations (> 2.50%) which limited K absorption^{2, 28}. As such, leaf K status for DxP Yangambi (DQ8) at 0.99% was low. A similar observation was reported by Jacquemard et al.⁶ 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. 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 among the planting materials studied.

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 status¹² and to produce high yield of 30 t FFB/ha, maintaining a correct combination of leaf N and K is required. Other workers have also reported a larger total nutrient requirement in clonal palms with a large yield potential (32.3 t/ha) when compared to DxP palm yield at 19.4 t/h²⁹. 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 DxP palm. K use efficiency in the clonal palm also increased by 51% when compared to that in DxP palm at 13.90 kg oil/kg K. Therefore, besides selecting higher productivity of palms for efficient oil production, an evaluation of the leaf nutrient concentrations, particularly Ca, deserves further investigation.

5. Conclusions

There were significant differences in all the leaf nutrient values for both terrain and irrigated conditions. For non-irrigated palms, most of the leaf nutrient values were high, particularly for leaf K and Mg which were almost 10% higher than the irrigated palms. Most of the leaf nutrient values in palms grown on the undulating area were also high especially for leaf Mg and K.

Leaf K concentrations for DxP Yangambi-DQ8 were consistently 15-20% lower than AVROS-A122 in all the growing conditions. The planting materials which produced high oil yields 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. The current generalized leaf nutrient critical levels used for evaluation 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.

6. 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 and Mr. Chin Cheuk Weng who provided the planting materials as well as the staff of the Agronomy Unit, who ensured the success of this project. Appreciation is also extended to Mr. Goh Kah Joo of Applied Agricultural Research Sdn. Bhd. for useful discussions.

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