Some keys points on palm nutrition diagnosis

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Abstract

The reaction of two genotypes to the same nitrogen–phosphorus–potassium (NPK) fertilisation policy with different magnesium (Mg) fertilisation regimes was studied in two adjacent factorial-design experiments on a mineral soil in Indonesia. The different Mg-fertilisation regimes were chosen after observing contrasted foliar Mg contents in the two different trials. The first experiment (ALCP61—planted with (DA5D×DA3D) × LM2T material with a low foliar Mg signature) received dolomite at a higher rate than in the second experiment (ALCP62—planted with a high foliar Mg signature with (DA5DxDA3D) × LM311P material). After 10 years of this different fertilisation regime, yield was evaluated as well as nutrition of oil palm through foliar and rachis analysis, complemented with soil analysis. The high Mg foliar content in the ALCP62 trial misled us to thinking that Mg fertilisation was not needed. Indeed, the limited supply of dolomite in ALCP62 induced changes in the cation equilibrium which was prejudicial to the nutrient balance in the leaf, as well as in the soil, especially when large amounts of potassium chloride were applied. It acidified the soil, decreased the exchangeable calcium and consequently the available P and total P, leading to an imbalanced palm nutrition which affected production. It allows us to conclude that the differences in foliar contents (Mg in this study) are specific to certain genotypes and need to be considered as such. Therefore, it is important to improve our knowledge in the nutrition × genotype interactions to obtain reliable indicators for responsible fertiliser management.

Introduction

Leaf analysis and fertiliser trials are widely used in oil palm estates to assess nutrient status and fertiliser requirements of the crop (Caliman et al. 1994). Optimal yields correspond to specific leaf nutrient contents and leaf analysis indicates the most limiting nutrients (Foster 2003). Yield response surfaces obtained from factorial fertiliser trials and leaf nutrient concentration response surfaces to fertiliser application compared with commercial leaf data allow determination of corrective fertiliser requirements (Webb 2009). Among those specific leaf nutrient contents, the nitrogen/phosphorus (N/P) balance governs P nutrition, and optimum P values are calculated from optimum leaf N values (Tampubolon et al. 1990). However, contrasted foliar levels according to the genetic origin of the planting material have been observed (Jacquemard et al. 2010) and it is assumed that target nutrient levels may differ according to genetic origins (Ollivier et al. 2013). This is the case in the experiment presented here, preliminary results of which were described by Jacquemard et al. (2010). The present results, which correspond to the latest round of observations, are compared with the chemical characteristics of the soil collected at the end of experimentation.

Material and methods

Two factorial trials were set up side by side at the Aek Loba plantation (North Sumatra) with planting material of two contrasted foliar Mg content types

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(ALCP61 and ALCP62) to study the effect of four fertilisers on mineral nutrition and production.

Aek Loba soils are rhyolitic soils of volcanic origin derived from Lake Toba–erupted material commonly called Toba acid tuffs. The soils at Aek Loba are very sandy and acidic, with a low cation exchange capacity (CEC) as measured by the cobaltihexamine method (Ciesielski et al. 1997) (Table 1).

Table 1. Soil (0–20 cm depth) and rainfall characteristics of trial locations

Characteristic	ALCP61	ALCP62
Organic matter (%)	2.23	2.12
pH	5.37	5.08
Cation exchange capacity ($cmol^{+}kg^{-1}$)	2.86	2.53
Clay (%)	16.5	17.4
Silt (%)	10.9	8.3
Sand (%)	72.6	74.3
Mean annual rainfall (mm) 1998–2008	2,396	2,396

The first trial (ALCP61) was planted with (DA5D×DA3D) × LM2T self material. The second (ALCP62) was planted with (DA5D×DA3D) × LM311P. LM311P is a pisifera form of LM6. The two trials were set up and planted in 1989.

The design comprises three factors—N, P and potassium (K)—studied at three levels. Fertiliser treatments were first applied in 1992; the N and K rates were applied as two split applications per year. From the beginning of the experiment, foliar magnesium (Mg) contents were found to be significantly different, with 0.251% and 0.338% for ALCP61 and ALCP62, respectively, observed in 1993. This discrepancy continued and the different Mg nutrition regimes were started in 1997. The ALCP61 experiment, showing a low foliar Mg signature, received dolomite at a higher rate (average application of 0.75 kg/palm/year) than the ALCP62 experiment which expressed a high foliar Mg signature (average application of 0.25 kg/palm/year) and in which foliage never shows Mg deficiency symptoms. A change in the potassium chloride (KCl) rate was made in 1999 (Table 2).

These experiments ran until 2007. Crude palm oil (CPO) yield was evaluated in 2006 and 2007 as well as nutrition of oil palm through foliar and rachis analysis. Soil sampling and analyses were implemented at the end of experiment in the contrasted treatments plots (N0P0K0, N0P2K2, N2P0K2, N2P2K0 and N2P2K2 in both trials, completed with N2P2K1 in ALCP61and with N1P0K1, N1P1K1 and N1P2K1 in ALCP62).

Table 2. Fertiliser treatments (kg/palm/year)

	Level 0	Level 1	Level 2
Urea	0.0	1.0	3.0
Rock phosphate (RP)	0.0	0.5	1.5
Potassium chloride (KCl)			
before 1999	0.0	1.0	3.0
since 1999	1.0	2.0	4.0
Dolomite ALCP61		0.5	1.0
Dolomite ALCP62	0.0	0.5	

Results and discussion

After 15 years of testing combinations of fertilisers and nearly 10 years of different Mg nutrition regimes, yield results obtained in the last 2 years of trial observation are shown in Table 3.

Table 3. Crude palm oil (CPO) yields (2006–2007) predicted for different nitrogen–phosphorus–potassium–magnesium (NPKMg) fertiliser combinations from fitted response functions

(a) ALCP61

Treatment (kg/palm)				Predicted CPO (t/ha/year)
Urea	RP	KCl	Dolomite	
0	0	1	0.5	7.34
0	0	1	1	7.50
3	1.5	1	1	7.86
3	1.5	4	1	7.96

(b) ALCP62

Treatment (kg/palm)				Predicted CPO (t/ha/year)
Urea	RP	KCl	Dolomite	
0	0	1	0	6.23
0	0	2	0	6.56
0	0	2	0.5	6.83
0	0.5	2	0	6.93
0	0.5	2	0.5	7.21
1	0.5	2	0.5	7.57
1	1.5	2	0.5	7.68
1	1.5	4	0.5	6.61
3	1.5	4	0.5	6.12

Note: RP = rock phosphate; dolomite = calcium magnesium carbonate

Very high CPO yields were obtained in ALCP61, with an optimum crop yield (nearly 8 t/ha/year) reached with the maximum rates of fertiliser application, and 7.3 t/ha/year with only 1 kg KCl and 0.5 kg dolomite applied per year and per palm.

The results appeared more contrasted with ALCP62. The CPO yield was lower with the lowest rate (1 kg KCl/palm/year), but yield response to P application was vigorous (with an increase of 1.4 t/ha/year). The highest rate of P fertilisation gave optimum yield (7.68 t/ha/year), but increasing the N (urea) and/or the K uptake strongly depressed the yield by more than 1 t/ha.

The main effects of the K-fertiliser treatments on leaflet nutrient levels in frond 17 in the last 3 years of experiments are shown in Table 4. Potassium fertiliser at 2 kg/palm/year and 4 kg/palm/year significantly raised the concentration of K in the leaflets in ALCP61, but the levels are lower in ALCP62 and the significant threshold is reached with 4 kg/palm/year. As expected, exchangeable K observed in the soil increased with increasing KCl (Figure 1).

Considering the calcium (Ca) status in the leaflet, the levels were lower in ALCP62 than in ALCP61 as Ca brought in via the dolomite fertiliser was lower in ALCP62 than in ALCP61. We also observed a drop in calcium with the increasing rate of KCl (Table 4). The drop in foliar Ca contents with the increasing rate of KCl is consistent with what is observed in the exchangeable Ca in the soil (Figure 1). At highest rates of KCl, Cl combines with Ca to form calcium chloride which is leached. It is a decalcifying effect of K fertilisers.

In regards to Mg, the depressing effect of K fertiliser was very strong in ALCP61. The supply of 1 kg of dolomite maintained the Mg content at 0.182% in ALCP61 while a level of 0.221% was achieved in ALCP62 with nil application of dolomite. At equivalent supply of dolomite (0.5 kg/palm/year), foliar Mg content was 0.225% for ALCP62 versus 0.142% for ALCP61. For Mg, if the foliar analysis is consistent with the exchangeable Mg observed in the soil in ALCP61, it is not the case for ALCP62. Because of the little supply of dolomite in ALCP62, the exchangeable Mg in the soil was lower, but despite this low level, the contents in the leaflet remained at a high level (Table 4).

The imbalance in leaflet N and P contents (Figure 2) and the exchangeable P and total P in the soil (Figure 3) could explain the drop in yield observed for ALCP62, especially when the high rate of K fertilisers was applied.

The low P content in leaflets observed at high levels of K was also consistent with what we observed in the exchangeable P measured with the Olsen Dabin method (Dabin 1967) and total P in the soil, which decreased dramatically.

The drop in leaflet P content was much less accentuated in ALCP61, the available P was maintained and the total P remained at a satisfactory level (Figure 3).

We observed previously that the decrease in the exchangeable Ca content in the soil was more pronounced in ALCP62, increasing the acidification of the soil. We assume that the different forms of phosphoric acid not fixed to the calcium ions disappeared

Table 4. Main effects of potassium and magnesium fertilisers (kg/palm/year) on leaflet nutrient levels (2006–2008)

Treatment	Nutrient	Nutrient level (%) by fertiliser regime				
		KCl 1	KCl 2	KCl 4	Dol. 0.5	Dol. 1
ALCP61	Potassium	0.859c	0.938b	1.061a	0.972a	0.934b
	Calcium	0.891a	0.890a	0.844b	0.885	0.865
	Magnesium	0.189a	0.162b	0.135c	0.142b	0.182a
					Dol. 0	**Dol. 0.5**
ALCP62	Potassium	0.843b	0.838b	0.886a	0.858	0.845
	Calcium	0.849ab	0.873a	0.815b	0.818	0.821
	Magnesium	0.239a	0.220b	0.210b	0.221	0.225

Note: KCl = potassium chloride; Dol. = dolomite; within the same row and within each nutrient addition, numbers followed by the same letter are not significantly different ($p < 0.05$)

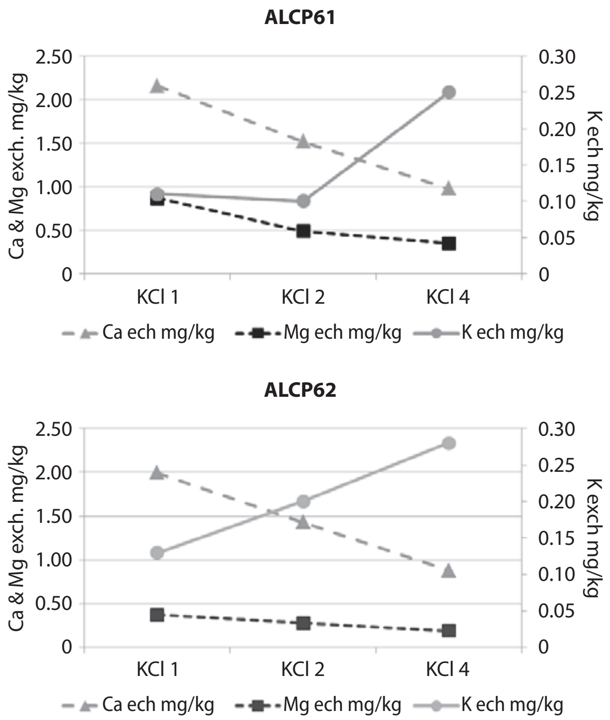

Figure 1. Effects of potassium fertilisers on soil exchangeable cations K, Ca, Mg (0–20 cm) in the two treatments (2008)

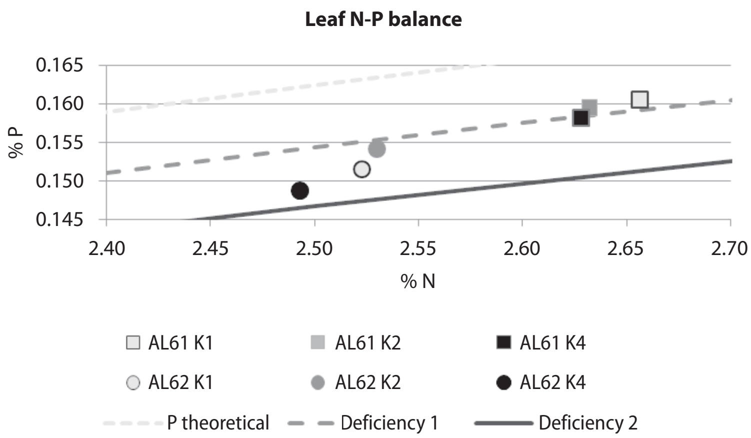

Figure 2. Leaflet nitrogen (N) and phosphorus (P) content equilibrium (2006–2008) (P theoretical value using Tampubolon equation)

because they were combined with aluminium or iron and were no longer available.

The Mg and related Ca brought in with the dolomite and the P status were the key issues of the experiment. Since the beginning of the trial, the very significant differences in the leaf Mg content between the two types of planting material led to a subdivision for each experiment with the consequences related previously. The high leaflet Mg content observed in ALCP62 was not compensated by sufficient magnesium-calcic fertilisers and led to a depletion of Ca and Mg in the soil accentuated with high KCl and urea applications. The decrease of exchangeable Ca and consequently the available P and total P led to an imbalanced palm nutrition which affected production.

These observations allow us to highlight that foliar diagnosis need to be taken with caution to assess nutrient status and fertiliser requirements of the crop. In this example, the LM311P material showed very high foliar Mg levels even when Mg inputs were nil and are most probably limiting sustained production. The method of determining Mg fertilisation through foliar analysis is therefore inappropriate for this material which behaves very differently from LM2T material. Another diagnostic tool has then to be used to predict deficiencies for crosses of this kind. This confirms that differences in foliar contents are often specific to certain genotypes and need to be considered as such. Therefore, it is important to improve our knowledge in the nutrition × genotype interactions to obtain reliable indicators for a responsible fertiliser management.

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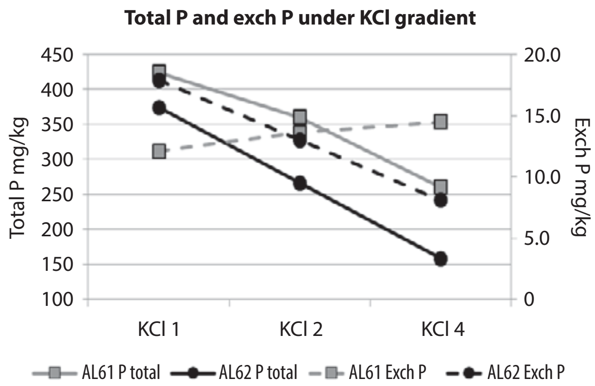

Figure 3. Exchangeable phosphorus (P) and total P in soil (0–20 cm depth)