THE EFFECTS OIL PALM EMPTY FRUIT BUNCHES ON OIL PALM NUTRITION AND YIELD, AND SOIL CHEMICAL PROPERTIES

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ABSTRACT

Mulching with oil palm empty fruit bunches (EFB) supplemented with inorganic fertilizer is widely practiced in oil palm plantations but with little evidence in support. In the absence of technical information, estates are applying large amounts of N and K fertilizers with the EFB due to the need to maintain high yield. This study was initiated to study the effects of applying N and K fertilizers together with mulching on oil palm nutrition and yield and the soil chemical properties. Three fertilizer rates were applied at two frequencies together with three rates of EFB in a 2 m band in the inter-rows. The experiment was conducted on 17-year-old palm planted on Durian series soil. Application of EFB at 37.5 t ha^{-1} yr^{-1} together with inorganic N and K fertilizers at rate 1 (0.735 kg N and 1.75 kg K palm^{-1} yr^{-1}) improved the leaf N and K levels, bunch number, bunch weight and fresh fruit bunch yield, while leaf Mg was depressed. EFB mulching also improved the soil exchangeable K, Ca and Mg and pH. The frequency of fertilizer application did have any effect on the leaf nutrient levels and yield. Thus, EFB mulching supplemented with N and K fertilizers should always be advocated for improving oil palm nutrition and yield.

Keywords: empty fruit bunch, mulch, oil palm nutrition.

INTRODUCTION

The beneficial effects of EFB mulching on oil palm growth and yield have been known since 1934 (Abdullah *et al.*, 1987). The main constraints to EFB application are the high cost, storage, distribution and pests (Turner and Gillbanks, 1974; Hartley, 1980), but the tangible benefits to be accrued outweigh its practical disadvantages. The results from direct EFB application are generally better vegetative growth, palm nutrition and yield (Chan and Goh, 1978; Lim and Pillai, 1979; Khoo and Chew, 1979; Gurmit *et al.,* 1981; Chan *et al.*, 1980; Loong *et al.*, 1987; Lim and Chan, 1987). The positive responses are attributed to improvement in the soil moisture regime, soil structure, organic matter content and microbial activity, and reduction in soil erosion and nutrient losses and soil surface temperature (Chan *et al.*, 1986; Hoong and Nadarajah, 1988). At present, the application of EFB to mature palms at 37.5 t ha^{-1} yr^{-1} is a common estate practice (Loong *et al.*, 1987).

The yield increases are enhanced when the mulching is supplemented with inorganic fertilizer (Loong *et al.*, 1987; Lim and Chan, 1987). The supplementation is necessary due to the slow release of nutrients from the EFB. The EFB is usually applied in a 2 m wide band in the inter-rows (frond path) which alternate with the harvesting rows. In the absence of scientific data, estates have been applying large amounts of N and K fertilizers with the EFB because of the need to maintain high yields. Research on the practice of combining EFB mulching with inorganic nutrient application is limited. This study was therefore undertaken to investigate the effects of EFB mulching with inorganic N and K fertilizer application to determine the optimum rates and frequency of EFB and inorganic fertilizer application for mature oil palm.

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MATERIALS AND METHODS

The experiment was conducted on 17-year-old DxP oil palm (*Elaeis guineensis* Jacq.) planted on Durian series soil (Plinthaquic Paleudult). Three rates of EFB were applied, *viz*. 0 (M0), 37.5 (M1) and 75 (M2) t ha^{-1} yr^{-1}. The EFB was obtained fresh from a mill and laid in a 2 m band in the inter-rows. The EFB was packed closely so that there were few gaps in between. At 37.5 t ha^{-1} yr^{-1}, it was laid in a single layer, while at 75 t ha^{-1} yr^{-1} in two layers.

Three rates of inorganic nitrogen were applied, *viz*. 0 (N0), 0.735 (N1) and 1.47 (N2) kg $palm^{-1}$ yr^{-1}. The fertilizer used was sulphate of ammonia (21% N). The three rates of K used were 0 (K0), 1.75 (K1) and 3.50 (K3) kg $palm^{-1}$ yr^{-1} from muriate of potash (50% K). The N and K fertilizers were applied at one (F1) or three (F2) times per year. The quantity of fertilizers applied was divided into equal amounts in F2. The fertilizers were applied on the EFB and, in the treatments without mulching, on the inter-line frond piles.

Phosphorus (157 kg ha^{-1}) and magnesium (204 kg ha^{-1}) were applied in all the treatments once per year as phosphate rock and kieserite, respectively.

The treatments were therefore 3 EFB rates x 3 N rates x 3 K rates x 2 fertilizer frequencies which should have given a total of 54 combinations. However, the higher rates of N and K at F1 were not included as the sheer amounts of fertilizers to be applied at one time made the treatments impractical. Thus, the final combinations were reduced to 39. There were three replicates, arranged in a randomized complete block with split plot design. The main plots were the EFB rates and the split plots the combinations of N and K fertilizers with frequency of fertilizer application. The total number of sub-plots was 117.

Each sub-plot consisted of 16 palms separated with isolation trenches (0.1 m wide x 1.0 m deep) to separate the sub-plots. De-silting of the trenches was done every six months.

Leaf tissue was sampled from Frond 17 yearly from all the 16 palms in the sub-plot and analysed for N, P, K and Mg. Yield was measured by weighing the fresh fruit bunches (FFB) from each plot and the yearly total derived using the density of 148 palms ha^{-1}. The number of fruit bunches produced was also recorded.

Soil samples were collected at the end of the experiment (after two years) at 0-15 cm and 15-30 cm depths and analysed for total N, ammonium acetate exchangeable K, Ca and Mg, and organic carbon.

The data obtained were statistically analysed using analysis of variance (Cochran and Cox, 1975).

RESULTS

Leaf Nitrogen (N) Concentration

The leaf N concentration at the beginning of the experiment did not show any significant differences between the treatments. At the end of the experiment, there was a significant positive interaction between mulching and N (M x N interaction). Thus, the response was higher with M and N applied together than the sum of their individual effects (*Table 1*). The interaction gave a

TABLE 1. LEAF NITROGEN LEVELS (%)

		Sampling time					
		Jan 1995			Dec 1996		
Treatment		N0	N1	N2	N0	N1	N2
	0	2.57[a]	2.68[a]	2.71[a]	2.28[a]	2.75[a]	2.78[a]
M	1	2.69[a]	2.74[a]	2.76[a]	2.52[b]	2.80[a]	2.78[a]
	2	2.64[a]	2.64[a]	2.72[a]	2.75[b]	2.83[a]	2.92[b]
		N0	N1	N2	N0	N1	N2
	0	2.63[a]	2.67[a]	2.69[a]	2.44[a]	2.78[a]	2.82[a]
K	1	2.66[a]	2.71[a]	2.76[a]	2.53[a]	2.81[a]	2.84[a]
	2	2.61[a]	2.69[a]	2.75[a]	2.58[a]	2.79[a]	2.81[a]
		K0	K1	K2	K0	K1	K2
	0	2.64[a]	2.68[a]	2.65[a]	2.57[a]	2.60[a]	2.64[a]
M	1	2.71[a]	2.76[a]	2.73[a]	2.66[a]	2.77[a]	2.68[a]
	2	2.64[a]	2.69[a]	2.67[a]	2.81[a]	2.82[a]	2.86[a]
		F1	F2		F1	F2	
	0	2.61[a]	2.70[a]	-	2.56[a]	2.64[a]	-
M	1	2.74[a]	2.72[a]	-	2.71[b]	2.70[a]	-
	2	2.68[a]	2.65[a]	-	2.85[b]	2.82[b]	-

Note: Means within the same column with the same superscript are not significantly different at P = 0.05.

leaf N of 2.92% while inorganic N or EFB application alone only raised it to 2.78% and 2.75%, respectively, for the N2 and M2 treatments. No other significant interaction was detected.

Leaf Phosphorus (P) Concentration

EFB mulching with or without N application did not significantly increase leaf P (*Table 2*). Application of inorganic K fertilizer and the different frequencies of fertilizer application also did not elicit any significant response. No significant interaction between treatments was detected.

Leaf Potassium (K) Concentration

There were significant increases in leaf K from mulching and the application of N and K fertilizers (*Table 3*). The M x N, M x K and M x N x K interactions also produced significantly higher leaf K concentrations. However, N x K and K x F did not show any significant effect.

TABLE 2. LEAF PHOSPHORUS LEVELS (%)

		Sampling time					
		Jan 1995			Dec 1996		
Treatment		N0	N1	N2	N0	N1	N2
	0	0.16[a]	0.16[a]	0.17[a]	0.15[a]	0.17[a]	0.17 [a]
M	1	0.17[a]	0.17[a]	0.17[a]	0.16[a]	0.17[a]	0.17 [a]
	2	0.17[a]	0.17[a]	0.17[a]	0.17[a]	0.17[a]	0.17 [a]
		N0	N1	N2	N0	N1	N2
	0	0.16[a]	0.17[a]	0.17[a]	0.16[a]	0.17[a]	0.18 [a]
K	1	0.16[a]	0.16[a]	0.17[a]	0.16[a]	0.17[a]	0.17 [a]
	2	0.16[a]	0.16[a]	0.17[a]	0.17[a]	0.17[a]	0.17 [a]
		K0	K1	K2	K0	K1	K2
	0	0.16[a]	0.16[a]	0.16[a]	0.17[a]	0.17[a]	0.16 [a]
M	1	0.17[a]	0.17[a]	0.11[a]	0.17[a]	0.17[a]	0.17 [a]
	2	0.17[a]	0.17[a]	0.17[a]	0.17[a]	0.17[a]	0.17 [a]
		F1	F2		F1	F2	
	0	0.16[a]	0.16[a]	-	0.17[a]	0.17[a]	-
M	1	0.17[a]	0.17[a]	-	0.17[a]	0.17[a]	-
	2	0.17[a]	0.17[a]	-	0.17[a]	0.17[a]	-

Note: Means within the same column with the same superscript are not significantly different at P = 0.05.

TABLE 3. LEAF POTASSIUM LEVELS (%)

		Sampling time					
		Jan 1995			Dec 1996		
Treatment		N0	N1	N2	N0	N1	N2
	0	1.07[a]	1.12[a]	1.12[a]	0.92[a]	1.04[a]	1.12[a]
M	1	1.10[a]	1.10[a]	1.08[a]	1.09[b]	1.20[b]	1.17[b]
	2	1.19[b]	1.19[b]	1.19[a]	1.22[c]	1.24[b]	1.21[b]
		N0	N1	N2	N0	N1	N2
	0	1.10[a]	1.10[a]	1.13[a]	1.05[a]	1.12[a]	1.13[a]
K	1	1.13[a]	1.15[a]	1.12[a]	1.09[a]	1.17[a]	1.16[a]
	2	1.11[a]	1.16[a]	1.15[a]	1.08[a]	1.20[a]	1.21[a]
		K0	K1	K2	K0	K1	K2
	0	1.07[a]	1.11[a]	1.12[a]	0.92[a]	1.09[a]	1.07[a]
M	1	1.07[a]	1.13[a]	1.08[a]	1.15[b]	1.15[b]	1.16[b]
	2	1.19[b]	1.16[b]	1.22[b]	1.23[c]	1.18[b]	1.25[c]
		F1	F2		F1	F2	
	0	1.12[a]	1.08[a]	-	1.01[a]	1.04[a]	-
M	1	1.04[a]	1.14[a]	-	1.15[a]	1.16[a]	-
	2	1.22[a]	1.16[a]	-	1.26[a]	1.19[a]	-

Note: Means within the same column with the same superscript are not significantly different at P = 0.05.

Leaf Magnesium (Mg) Concentration

Significant M x N and M x K interactions were detected in leaf Mg. There was a significant decrease in leaf Mg due to EFB application (*Table 4*). The frequency of fertilizer application did not have any effect.

Fresh Fruit Bunch (FFB) Yield

Mulching and mulching with addition of N fertilizer increased the FFB yield, but the N and K fertilizers alone did not have any significant effect (*Table 5*). However, when both N and K were applied with EFB, there was an enhanced increase. No significant N x K and M x N x K interactions were observed.

Bunch Number (BN)

Mulching, with or without N, increased BN (*Table 5*), but the increase was higher with N. K fertilizer, with or without EFB, and the frequency of application did not have any effect (*Table 5*).

Average Bunch Weight (ABW)

EFB and inorganic fertilizer increased ABW (*Table 5*). There were also positive responses from the M x N and M x K interactions. The frequency of fertilizer application and M x N x K interaction did not affect this parameter.

Soil Analysis After the Experiment

Soil pH. EFB and inorganic N both affected the soil pH in the two depths sampled, although in different ways. Mulching increased the pH while N reduced it. When jointly applied, the pH was increased (*Table 6*). K did not have any effect.

Soil organic carbon. EFB, with or without N and K fertilizers, increased soil organic carbon in both the depths. There were no interaction effects (*Table 7*).

Total nitrogen. EFB increased total soil N in both soil depths (*Table 8*). Inorganic N alone only increased it in the 15-30 cm depth, while inorganic K fertilizer did not have any effect.

Exchangeable K. Mulching and K application individually increased soil exchangeable K in both soil depths. But N depressed it, especially in the 15-30 cm depth. Combining EFB and N gave an increase (*Table 9*).

Exchangeable calcium. EFB increased the soil exchangeable Ca, but the sole application of N decreased it (*Table 10*). Application of K fertilizer did not have any effect.

Exchangeable magnesium. Mulching increased the exchangeable Mg (*Table 11*) but N reduced it. K did not have any effect.

TABLE 4. LEAF MAGNESIUM LEVELS (%)

		Sampling time					
		Jan 1995			Dec 1996		
Treatment		N0	N1	N2	N0	N1	N2
	0	0.24[a]	0.23[a]	0.23[a]	0.29[b]	0.24[b]	0.24[b]
M	1	0.24[a]	0.23[a]	0.22[a]	0.26[b]	0.21[a]	0.20[a]
	2	0.23[a]	0.22[a]	0.22[a]	0.23[a]	0.20[a]	0.20[a]
		N0	N1	N2	N0	N1	N2
	0	0.24[a]	0.23[a]	0.23[a]	0.27[a]	0.23[a]	0.21[a]
K	1	0.24[a]	0.23[a]	0.23[a]	0.25[a]	0.22[a]	0.22[a]
	2	0.24[a]	0.23[a]	0.22[a]	0.25[a]	0.21[a]	0.21[a]
		K0	K1	K2	K0	K	K2
	0	0.24[a]	0.24[a]	0.23[a]	0.29[b]	0.25[b]	0.23[a]
M	1	0.23[a]	0.23[a]	0.22[a]	0.23[a]	0.22[ab]	0.22[a]
	2	0.22[a]	0.23[a]	0.23[a]	0.20[a]	0.21[a]	0.22[a]
		F1	F2		F1	F2	
	0	0.23[a]	0.24[a]	-	0.25[a]	0.26[a]	-
M	1	0.22[a]	0.23[a]	-	0.22[a]	0.22[a]	-
	2	0.22[a]	0.22[a]	-	0.21[a]	0.21[a]	-

Note: Means within the same column with the same superscript are not significantly different at P = 0.05.

TABLE 5. FRESH FRUIT BUNCH YIELD (t ha^{-1} yr^{-1}), NUMBER OF FRUIT BUNCHES (ha^{-1} yr^{-1}) AND AVERAGE BUNCH WEIGHT (kg)

Treatment		Fresh Fruit Weight			Treatment		Fruit Bunch Number			Treatment		Average Fruit Bunch Weight		
		N0	N1	N2			N0	N1	N2			N0	N1	N2
	0	21.03[a]	32.84[a]	34.20[a]		0	990[a]	1 262[a]	1 297[a]		0	20.92[a]	25.94[a]	26.35[a]
M	1	29.94[b]	35.57[b]	37.19[b]	M	1	1 197[b]	1 304[b]	1 383[b]	M	1	25.07[b]	27.36[a]	26.97[a]
	2	34.03[c]	35.44[b]	35.75[b]		2	1 256[b]	1 346[b]	1 329[b]		2	27.13[b]	26.39[a]	26.88[a]
		N0	N1	N2			N0	N1	N2			N0	N1	N2
	0	27.60[a]	33.61[a]	35.23[a]		0	1 134[a]	1 269[a]	1 349[a]		0	23.69[a]	26.51[a]	26.15[a]
K	1	27.79[a]	34.97[a]	36.48[a]	K	1	1 122[a]	1 349[a]	1 329[a]	K	1	24.52[a]	25.97[a]	27.45[a]
	2	29.61[a]	35.27[a]	35.43[a]		2	1 187[a]	1 293[a]	1 331[a]		2	24.90[a]	27.21[a]	26.56[a]
		K0	K1	K2			K0	K1	K2			K0	K1	K2
	0	26.40[a]	30.00[a]	31.68[a]		0	1 134[a]	1 179[a]	1 238[a]		0	22.86[a]	24.99[a]	25.37[a]
M	1	34.26[b]	34.58[b]	33.85[b]	M	1	1 289[b]	1 310[b]	1 285[a]	M	1	26.59[b]	26.41[b]	26.40[b]
	2	35.79[b]	34.65[b]	34.78[b]		2	1 330[b]	1 312[b]	1 289[a]		2	26.90[b]	26.55[b]	26.94[b]
		F1	F2				F1	F2				F1	F2	
	0	28.83[a]	29.88[a]	-		0	1 179[a]	1 188[a]	-		0	23.92[a]	24.88[a]	-
M	1	35.38[b]	33.08[b]	-	M	1	1 325[b]	1 264[b]	-	M	1	26.77[a]	26.16[a]	-
	2	34.50[b]	35.65[b]	-		2	1 296[b]	1 324[b]	-		2	26.59[a]	27.01[a]	-

Note: Means within the same column with the same superscript are not significantly different at P = 0.05.

TABLE 6. CHANGES IN SOIL pH WITH EMPTY FRUIT BUNCH AND FERTILIZER APPLICATION

		Soil depth					
		0 - 15 cm			15 - 30 cm		
Treatment		N0	N1	N2	N0	N1	N2
	0	5.24[a]	4.62[a]	4.28[a]	4.64[a]	4.38[a]	4.18[a]
M	1	6.04[b]	5.40[b]	4.81[b]	5.52[b]	4.87[b]	4.49[b]
	2	6.18[b]	5.85[b]	5.16[b]	6.01[b]	5.42[b]	4.71[b]
		N0	N1	N2	N0	N1	N2
	0	5.69[a]	5.21[a]	4.73[a]	5.35[a]	4.76[a]	4.38[a]
K	1	5.96[a]	5.23[a]	4.78[a]	5.61[a]	4.88[a]	4.44[a]
	2	5.82[a]	5.43[a]	4.74[a]	5.21[a]	5.02[a]	4.56[a]
		K0	K1	K2	K0	K1	K2
	0	4.56[a]	4.73[a]	4.86[a]	4.32[a]	4.42[a]	4.46[a]
M	1	5.40[b]	5.49[b]	5.35[b]	4.85[b]	5.02[b]	5.00[b]
	2	5.67[b]	5.75[b]	5.77[b]	5.32[b]	5.49[b]	5.33[b]
		F1	F2		F1	F2	
	0	4.87[a]	4.57[a]	-	4.53[a]	4.27[a]	-
M	1	5.44[b]	5.39[b]	-	4.97[a]	4.94[b]	-
	2	5.87[b]	5.59[b]	-	5.46[b]	5.30[b]	-

Note: Means within the same column with the same superscript are not significantly different at P = 0.05.

TABLE 7. CHANGES IN SOIL ORGANIC CARBON WITH EMPTY FRUIT BUNCH AND FERTILIZER APPLICATION

		Soil depth					
		0 - 15 cm			15 - 30 cm		
Treatment		N0	N1	N2	N0	N1	N2
	0	1.65[a]	1.77[a]	1.59[a]	1.31[a]	1.21[a]	1.16[a]
M	1	2.88[b]	2.80[b]	2.92[b]	1.75[b]	1.64[b]	1.96[b]
	2	2.85[b]	3.01[b]	2.98[b]	1.93[b]	1.89[b]	2.24[b]
		N0	N1	N2	N0	N1	N2
	0	2.40[a]	2.58[a]	2.39[a]	1.68[a]	1.60[a]	1.64[a]
K	1	2.57[a]	2.45[a]	2.59[a]	1.76[a]	1.51[a]	1.82[b]
	2	2.41[a]	2.55[a]	2.51[a]	1.56[a]	1.62[a]	1.90[b]
		K0	K1	K2	K0	K1	K2
	0	1.59[a]	1.77[a]	1.64[a]	1.21[a]	1.29[a]	1.19[a]
M	1	2.94[b]	2.76[b]	2.90[b]	1.84[b]	1.66[b]	1.85[b]
	2	2.84[b]	3.08[b]	2.92[b]	1.88[b]	2.15[b]	2.04[b]
		F1	F2		F1	F2	
	0	1.69[a]	1.65[a]	-	1.28[a]	1.18[a]	-
M	1	2.81[b]	2.93[b]	-	1.70[b]	1.86[b]	-
	2	2.96[b]	2.93[b]	-	2.07[b]	1.97[b]	-

Note: Means within the same column with the same superscript are not significantly different at P=0.05.

DISCUSSION

There was a significant M x N interaction affecting the leaf nutrient levels, generally raising them. EFB supplemented with N fertilizer increased leaf N, P, K and Mg over and above the effects of EFB or N alone. Nitrogen from the decomposing EFB must have been released in the second year and taken up by the palms, since in a decomposition experiment carried out earlier (Lim and Zaharah, 2000), no N was released in the first 10 months after application. In this experiment, the leaf N also increased with inorganic N application. The N level at N1 was the same as the level with EFB at rate 2. Leaf N increased significantly when EFB was applied at rate 2 and inorganic N at rate 2. The increased nutrient uptake with EFB could have been due to the more conducive environment resulting from the improved soil physical and chemical properties (Loong *et al.*, 1987; Lim and Chan, 1987). The increased rooting activity

TABLE 8. TOTAL NITROGEN CONCENTRATION (%) IN THE SOIL AFTER EMPTY FRUIT BUNCH AND FERTILIZER APPLICATION

		Soil depth					
		0 – 15 cm			15 - 30 cm		
Treatment		N0	N1	N2	N0	N1	N2
	0	0.17[a]	0.18[a]	0.16[a]	0.15[a]	0.13[a]	0.14[a]
M	1	0.36[b]	0.34[b]	0.34[b]	0.20[b]	0.18[b]	0.20[b]
	2	0.38[b]	0.40[b]	0.42[b]	0.21[b]	0.20[b]	0.25[b]
		N0	N1	N2	N0	N1	N2
	0	0.30[a]	0.32[a]	0.29[a]	0.20[a]	0.17[a]	0.17[a]
K	1	0.35[a]	0.30[a]	0.29[a]	0.19[a]	0.16[a]	0.21[a]
	2	0.27[a]	0.30[a]	0.33[a]	0.17[a]	0.18[a]	0.21[a]
		K0	K1	K2	K0	K1	K2
	0	0.17[a]	0.19[a]	0.17[a]	0.13[a]	0.16[a]	0.13[a]
M	1	0.36[b]	0.32[b]	0.36[b]	0.19[b]	0.18[a]	0.21[b]
	2	0.38[b]	0.44[b]	0.38[b]	0.21[b]	0.23[b]	0.23[b]
		F1	F2		F1	F2	
	0	0.17[a]	0.17[a]	-	0.14[a]	0.14[a]	-
M	1	0.35[b]	0.35[b]	-	0.18[b]	0.20[b]	-
	2	0.40[b]	0.40[b]	-	0.23[b]	0.22[b]	-

Note: Means within the same column with the same superscript are not significantly different at P = 0.05.

TABLE 9. SOIL EXCHANGEABLE POTASSIUM [cmol(+)/kg soil] WITH EMPTY FRUIT BUNCH AND FERTILIZER APPLICATION

		Soil depth					
		0 – 15 cm			15 - 30 cm		
Treatment		N0	N1	N2	N0	N1	N2
	0	0.95[a]	0.29[a]	0.33[a]	0.75[a]	0.28[a]	0.33[a]
M	1	1.25[b]	1.05[b]	0.76[b]	1.60[b]	1.24[b]	0.80[b]
	2	1.81[b]	2.08[b]	2.04[c]	2.28[c]	2.14[c]	1.66[c]
		N0	N1	N2	N0	N1	N2
	0	0.89[a]	0.84[a]	0.91[a]	1.23[a]	0.81[a]	0.57[a]
K	1	1.27[b]	1.07[b]	1.04[b]	1.54[b]	1.10[b]	0.97[b]
	2	1.84[c]	1.51[c]	1.18[b]	1.85[c]	1.75[c]	1.25[c]
		K0	K1	K2	K0	K1	K2
	0	0.09[a]	0.54[a]	0.94[a]	0.10[a]	0.41[a]	0.85[a]
M	1	0.70[b]	1.07[b]	1.28[b]	0.71[b]	1.32[b]	1.61[b]
	2	1.85[c]	1.77[c]	2.30[c]	1.80[c]	1.89[c]	2.39[c]
		F1	F2		F1	F2	
	0	0.57[a]	0.48[a]	-	0.50[a]	0.41[a]	-
M	1	0.91[b]	1.13[b]	-	1.26[b]	1.17[b]	-
	2	2.26[c]	1.69[c]	-	2.21[c]	1.84[c]	-

Note: Means within the same column with the same superscript are not significantly different at P = 0.05.

could have been another factor (Lim, 1989). In this experiment, the tertiary and quarternary roots of the oil palm had proliferated throughout the EFB as early as three weeks after application although no quantification of the root growth was done.

The significant M x K interaction affected leaf K and Mg contents. K was improved but Mg decreased due to the antagonistic effect between the two.

There was no significant interaction between M x F for all the nutrients tested. Thus, increasing the fertilizer application from one to three times per year with mulching did not have any beneficial effect on the palm nutrition. Even in the absence of mulching, there was no significant difference in the leaf nutrient levels between the two frequencies of fertilizer application. This is in contrast with earlier work by Chan and Rajaratnam (1975) who found that increasing the frequency improved fertilizer uptake. The reason may be that in this study, the 17-year-old palms had a dense canopy

TABLE 10. SOIL EXCHANGEABLE CALCIUM WITH EMPTY FRUIT BUNCH AND FERTILIZER APPLICATION [cmol(+)/kg soil]

		Soil depth					
		0 - 15 cm			15 - 30 cm		
Treatment		N0	N1	N2	N0	N1	N2
	0	4.90[a]	3.35[a]	1.98[a]	2.22[a]	1.47[a]	1.42[a]
M	1	14.09[b]	8.40[b]	3.70[b]	5.00[b]	2.68[b]	1.82[b]
	2	14.36[b]	11.45[b]	5.98[c]	6.63[b]	4.10[c]	2.57[c]
		N0	N1	N2	N0	N1	N2
	0	10.78[a]	7.89[a]	3.40[a]	5.15[a]	2.51[a]	1.68[a]
K	1	13.15[a]	8.09[a]	4.08[a]	5.23[a]	2.83[a]	2.10[a]
	2	9.41[a]	7.21[a]	4.17[a]	3.48[a]	2.92[a]	2.04[a]
		K0	K1	K2	K0	K1	K2
	0	3.39[a]	3.38[a]	3.46[a]	1.69[a]	1.64[a]	1.79[a]
M	1	9.44[b]	8.52[b]	8.22[b]	3.34[b]	3.12[b]	3.04[b]
	2	9.25[b]	13.43[c]	9.11[b]	4.31[b]	5.40[b]	3.60[b]
		F1	F2		F1	F2	
	0	4.11[a]	2.70[a]	-	2.43 [a]	0.97[a]	-
M	1	8.76[b]	8.70[b]	-	3.42[ab]	2.92[b]	-
	2	10.97[c]	10.22[c]	-	4.96 [b]	3.90[c]	-

Note: Means within the same column with the same superscript are not significantly different at P = 0.05.

TABLE 11. SOIL EXCHANGEABLE MAGNESIUM [cmol(+)/kg soil] WITH EMPTY FRUIT BUNCH AND FERTILIZER APPLICATION

		Soil depth					
		0 - 15 cm			15 - 30 cm		
Treatment		N0	N1	N2	N0	N1	N2
	0	1.84[a]	0.90[a]	0.71[a]	0.82[a]	0.49[a]	0.55[a]
M	1	5.03[b]	2.45[b]	1.07[b]	2.18[b]	0.98[b]	0.62[b]
	2	5.28	4.19[c]	2.49[c]	2.96[b]	1.79[c]	1.19[c]
		N0	N1	N2	N0	N1	N2
	0	4.22[b]	2.76[a]	1.38[a]	2.33[b]	1.05[a]	0.71[a]
K	1	4.74[b]	2.52[a]	1.45[a]	2.13[b]	1.10[a]	0.83[a]
	2	3.20[a]	2.26 [a]	1.44[a]	1.51[a]	1.11[a]	0.83[a]
		K0	K1	K2	K0	K1	K2
	0	1.18[a]	1.16[a]	1.11[a]	0.59[a]	0.60[a]	0.67[a]
M	1	3.29[b]	2.98[b]	3.28[b]	1.40[b]	1.25[b]	1.14[b]
	2	3.88[b]	4.57[c]	3.51[b]	2.09[c]	2.21[c]	1.64[c]
		F1	F2		F1	F2	
	0	1.49[a]	0.82[a]	-	0.91[a]	0.33[a]	-
M	1	2.74[b]	2.96[b]	-	1.37[b]	1.16[b]	-
	2	4.30[c]	3.67[c]	-	2.37[c]	1.60[c]	-

Note: Means within the same column with the same superscript are not significantly different at P = 0.05.

and the organic matter recycled from the fronds significantly reduced the fertilizer losses by leaching and run off.

There was also no N x K effect on the leaf nutrients which was also reported by Chan *et al.* (1992). The M x N x K interaction was only detected in leaf K.

A significant yield increase was obtained with the M x N and M x K interactions due to both higher BN and ABW when mulching was done with N and K fertilizers. The improved palm nutrition was evidence by the higher leaf nutrient levels from the interactions. Significant increases in yield were observed for the M1, N1 and K1 rates, but not for the M2, N2 and K2 rates.

Application of EFB also improved the soil chemical properties, especially exchangeable K. Similar observations were also reported by Rosenani *et al.* (1996). However, the pH increase was small compared to the increases obtained by the other workers (Loong *et al.*, 1987; Rosenani *et al.*, 1996).

This discrepancy was due to the type of N fertilizer used-ammonium sulphate instead of urea. The prolonged use of ammonium sulphate decreases the soil pH due to its acidifying effect.

From the economic viewpoint, it was very cost effective to apply EFB given the yield increase obtained. More of the N and K fertilizers applied were taken up due to a reduction in their losses from surface wash and leaching. Estates should therefore always exploit the use of EFB when it is available.

CONCLUSION

Application of EFB at 37.5 t ha^{-1} yr^{-1} together with N and K fertilizers at rate 1 improved leaf N and K levels, BN and yield. However, leaf Mg decreased with EFB application. Mulching with EFB also improved the soil exchangeable K, Ca and Mg and pH. The frequency of fertilizer application did not affect the leaf nutrient levels and yield of oil palm. Thus, applying EFB and supplementing it with N and K fertilizers should always be advocated to exploit their beneficial combined effects on oil palm nutrition and yield.

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