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DECOMPOSITION AND N & K RELEASE BY OIL PALM EMPTY FRUIT BUNCHES APPLIED UNDER MATURE PALMS

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The oil palm empty fruit bunch (EFB) is one of the major waste products of the oil palm industry and is currently used as an organic mulch in young and mature oil palm plantations. Afield experiment was set up to monitor EFB decomposition and N and K release for a period of 10 months with the EFB placed in single or double layers stacked along mature oil palm interrows with and without inorganic N and K fertilizers. The quantity of EFB applied was 37.5 t ha^{-1} applied in a single layer and 75 t ha^{-1} applied in a double layer. N was applied as ammonium sulphate and K as muriate of potash at three rates of 0, 3.5 and 7.0 kg fertilizers $palm^{-1}$ yr^{-1}. The frequency of fertilizer application was once and three times per year. Random samplings of EFB were taken from the single layer, and from the top and bottom layers of the double layer treatment and their dry weights, N and K concentrations determined.

The EFB dry matter loss followed an exponential model. There was a 50% loss in dry matter in the initial three months and 70% dry matter loss after eight months. The single layer EFB decomposed faster than the double layer top or bottom. Addition of inorganic N fertilizer enhanced significantly dry matter loss in the single layer EFB. Inorganic K fertilizer application did not significantly affect EFB decomposition for all treatments. Release of EFB-N was not detected during the 10-month period of the study. Release of EFB-K was very rapid during the initial stages of decomposition, with 90% of *it released after six months **of** decomposition. At 10 months, more than 99% **of** EFB-K had been released.*

INTRODUCTION

EFB is one of the major waste products that results after processing of fresh fruit bunches (FFB) in oil palm mills. About 22% of the FFB processed ends up as EFB. The nutrient content of EFB averages at 0.8% N, 0.1% P, 2.5% K and 0.2% Mg on a dry weight basis (Gurmit *et al.,* 1981). By the year 2000, Malaysia is projected to produce 2.2 million tonnes of EFB (Aini *et al.,* 1992). In the past, EFB was incinerated in the mill as a means to eliminate this waste as well as to provide energy for the boilers in FFB sterilization. The bunch ash produced, which is about 6.5% by weight of the EFB, contains about 30%-40% K_2O. The ash is used as a fertilizer for K and has been found to improve the yield of oil palm grown on acid coastal soils in Malaysia (Hew and Poon, 1973; Toh *et al.,* 1981).

The process of incineration was restricted by the Department of Environment (DOE) through the Environmental Quality Clean Air Regulation Act, 1978. This led to the utilization of EFB to be directly applied to oil palm fields. Long term experiments conducted have indicated that application of EFB to oil palm resulted in very favourable benefits in terms of oil palm growth and yield (Khoo and Chew, 1979; Lim and Chan, 1987). To ameliorate the slow release of nutrients from the EFB and to maintain a high soil nutrient content to sustain high oil palm yields, the addition of inorganic fertilizers on the EFB is considered necessary. The EFB is usually applied as a 2 m wide band in the interrows of the oil palm and N and K inorganic fertilizers applied onto the EFB band (Loong *et al.,* 1987; Lim and Chan, 1987; Chan *et al.,* 1992). Past studies on EFB application to oil palm did not clearly indicate the actual mechanisms on the role of EFB in increasing palm growth and yield. Most researchers have attributed the resultant palm benefits to the mulching effects of EFB and the release of nutrients from EFB without further explaining and quantifying the actual contribution of each of these two factors or what actual mechanisms are involved. Thus, the objective of this study was to acquire information on EFB decomposition and nutrients mineralized from two rates of EFB applied with different rates and frequencies of inorganic N and K fertilizers.

MATERIALS AND METHODS

The experiment was conducted in a 17-year-old DxP oil palm field planted on a Durian series soil (Plinthic Paleudult). Three rates of EFB (0, 37.5 and 75 t ha^{-1} yr^{-1}) were applied as a 2 m band in the oil palm interrow. The EFBs were arranged close to each other so that gaps between them were minimal. At 37.5 t ha^{-1} yr^{-1}, the EFB was applied as a single layer, and at 75 t ha^{-1} yr^{-1}, the EFB band was stacked as a double layer. Three rates of inorganic N (0, 0.735 and 1.47 kg N $palm^{-1}$ yr^{-1}) were applied as ammonium sulphate (21% N), while the three rates of K (0, 1.75 and 3.50 kg K $palm^{-1}$ yr^{-1}) were applied as muriate of potash (60% K_2O). These are equivalent to 0, 3.5 and 7.0 kg fertilizer palm-l yr^{-1}. The N and K fertilizers were applied either once or three times per year spread evenly over the EFB layer. The quantity of fertilizers applied was divided in equal amounts when applied at three times per year. The N and K fertilizers at the highest rate (7.0 kg $palm^1$ yr^{-1}), applied at the frequency of once per year were not made since this rate was considered to be too high an amount to be applied at one time. Each treatment had three replications with the plots arranged in a randomized complete block with split plot design. To assess the loss of dry matter, weighing of the EFB in the field was made on four EFB bunches randomly selected from each layer. A piece of nylon mesh was placed under this EFB for both single and double layer EFB for all treatments to facilitate weighing. Two whole EFB were randomly sampled from each treatment every four weeks to determine the moisture and N and K contents. The moisture content was determined using gravimetric analysis, while N was determined using semi-micro Kjeldahl procedure using salicylic acid to include nitrate and nitrite. K in the EFB was analysed by dry ashing and dissolving in nitric acid and determined by flame photometer.

Statistical Analysis of Data

The data obtained were subjected to the standard statistical analysis of Cochran and Cox (1975) and to non-linear regression analysis using an exponential model to determine goodness of fit as outlined by Statgraphics (1991).

The pattern of decline in dry matter weight and N and K remaining in the EFB were fitted using an exponential model of: $M_t = M_o \times e^{-kt}$, where, M_t is the mass at' time t, M_o the mass at time 0, e the exponential value, k the decomposition rate constant, and t the time after application in months.

RESULTS

Rate and Pattern of Dry Matter Loss

There was a significant decrease in dry matter weight with time of sampling *(Figure 1)*. The dry matter decrease was very rapid in the initial three months (50% of the original weight), slowly diminishing until about seven to eight months after which the decrease was very minimal. The rate of dry matter loss was fastest in the single layer followed by the double layer top and double layer bottom EFB.

The pattern of decline in dry matter weight followed the non-linear exponential model of $M_t = M_o \times e^{-kt}$, with significant r^2 values for all the treatments (*Table 1*). It was observed that the rate of decomposition of the single layer was the fastest followed by the double layer top and double layer bottom EFB (*Table* 1). The decomposition rate constant (k value) was 0.3469 for single layer, 0.3418 for double layer top and 0.2769 for double layer bottom. The single and double layer top EFB showed significantly faster weight loss than the double layer bottom EFB. There was no significant difference between single layer and double layer top in the rate of dry matter loss.

. The application of inorganic N fertilizer only showed significant increase in the rate of dry matter weight loss in single layer EFB with time. The decomposition rate constant (k value) increased from 0.3469 in the treatment without N, to 0.5138 when N was applied at rate 1 and 0.6415 at N rate 2. In the double top and bottom layer, the increase in k value was only observed at N2. The double layer EFB (top and bottom) weight loss was not significantly affected by the addition of inorganic N fertilizer. Split applications of N and K fertilizers were also found to be not significantly affecting the loss in dry matter weight of the EFB in all treatments. Inorganic K fertilizer applied once or three per year, did not significantly affect the dry matter weight loss of the EFB for all the treatments with time. The k values obtained for single layer and double layer top was around 0.4, 0.3 for the bottom double layer with and without K fertilizer application. The r^2 values obtained were highly significant for all treatments.

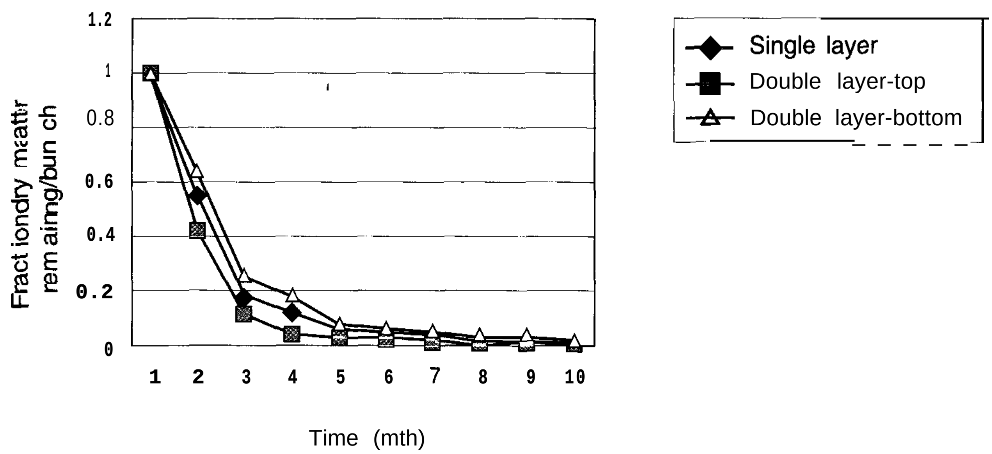

Figure 1. Fraction of EFB dry matter weight remaining per bunch with time of decomposition.

TABLE 1. CALCULATED LOSS IN DRY MATTER WEIGHTS OF EFB PLACED AS SINGLE LAYER AND DOUBLE LAYER IN THE OIL PALM ROWS WITH TIME

EFB treatments		N0	N1	N2	K0	K1	K2
Single layer	M_0	1.8612	2.2463	1.6628	2.0046	1.8461	2.0516
	k	0.3469	0.5138	0.6415	0.4223	0.4841	0.4929
	r^2	0.8147	0.8728	0.6494	0.7700	0.8442	0.8408
Double layer (Top)	M_0	1.8376	1.3868	1.6824	1.6913	1.5978	1.5561
	k	0.4418	0.3580	0.5451	0.4311	0.4203	0.4792
	r^2	0.7888	0.6226	0.8142	0.7294	0.7283	0.7303
Double layer (Bottom)	M_0	1.6276	1.8562	1.7713	1.8608	1.6836	1.6724
	k	0.2763	0.2609	0.3307	0.3033	0.2760	0.2561
	r^2	0.8599	0.9236	0.9300	0.9007	0.8363	0.8456

Regression equation: $M_t = M_0 \times e^{-kt}$

Where M_t is the mass at time t,
M_0 is the mass at time zero,
e is the exponential value,
k is the decomposition rate constant,
t is time after application in months.

N Release by Decomposing EFB

The mean monthly total N values indicated no discerning trend in EFB-N for all the three layers tested with and without the application of inorganic N and K fertilizers. This indicated that there was no observed release of N by these decomposing EFB placed under mature oil palm up to 10 months under field conditions (Table 2). The addition of inorganic N and K fertilizers did not show any significant difference in the EFB-N content with time.

K Release by Decomposing EFB

There was a significant decline in the K content in the EFB at each sampling time. On the average, there was a 35% decrease in the K content after one month, 70% after three months and 90% after six months in the field. After this time, there was a slow decline with more than 99% decline after 10 months in the field (Figure 2). The pattern of K release by the EFB followed the non-linear exponential model described in ***Table*** 3. The addition of

TABLE 2. N CONCENTRATION IN EFB WITH TIME

Month	Single layer EFB (g bunch-')	Double layer top EFB (g bunch-')	Double layer bottom EFB (g $bunch^{-1}$)
1	11.287	11.561	14.635
3	11.874	11.696	14.313
4	11.043	8.192	11.493
6	13.307	12.188	11.748
8	13.334	10.098	9.985
10	11.238	8.636	10.562
Standard error	0.935	0.708	0.691

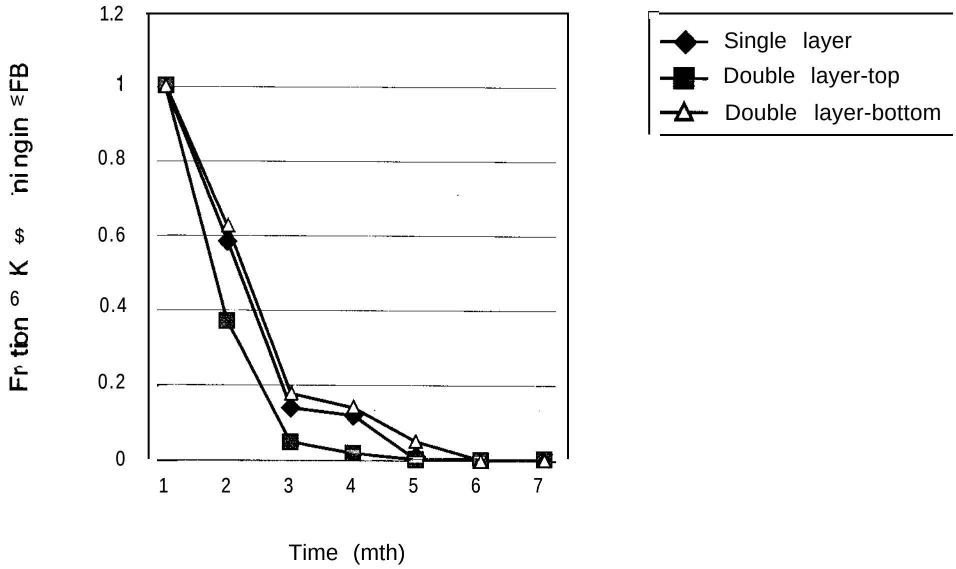

Figure 2. Fraction of total K remaining in the EFB with time of decomposition.

TABLE 3. CALCULATED LOSS IN K CONTENT OF EFB PLACED AS SINGLE AND DOUBLE LAYER IN THE OIL PALM ROWS WITH TIME

EFB		N0	N1	N2	K0	K1	K2
Single layer	M_0	20.6395	25.0882	23.8194	24.7276	20.0766	24.3251
	k	0.2740	0.4141	0.4792	0.3652	0.4239	0.3072
	r^2	0.7651	0.8513	0.7991	0.8155	0.7787	0.8988
Double layer (Top)	M_0	37.2552	29.5260	35.9601	48.7590	26.7033	23.5097
	k	0.4453	0.4805	0.5587	0.5691	0.4519	0.3516
	r^2	0.7180	0.9223	0.8516	0.8347	0.8586	0.9246
Double layer (Bottom)	M_0	34.6892	42.0698	46.5538	43.0483	38.5397	37.6420
	k	0.2624	0.2973	0.4005	0.3437	0.2997	0.2536
	r^2	0.9520	0.8585	0.9306	0.9433	0.8560	0.8751

Regression equation: $M_t = M_0 \times e^{-kt}$

where M_t is the mass at time t,
M_0 is the mass at time 0,
e is the exponential value,
k is the decomposition rate constant,
t is time after application in months.

inorganic N and K fertilizers to the EFB showed a general increase in the release of EFB-K. However, no significant differences were observed in the rate of EFB-K released due to the different rates of N and K added for all the EFB treatments.

DISCUSSION

The rapid decomposition in the initial stages and its declining rate of decomposition at the later months after being placed in the field was largely due to the inherent biochemical characteristics of the EFB, where the sugars, hemicellulose, cellulose and proteins decompose earlier than the lignins and waxes (Greens *et al.*, 1995; Rosenani *et al.*, 1996). Total disintegration of the EFB was after seven months in the field. The greatest weight loss was observed in the first phase of decomposition during the first three months. Thereafter, there was no change in the dry matter weights up to 10 months in the field. This pattern follows the general phenomena of decomposition of most organic residues which is normally characterized by an initial fast and a later slow phase (Jenkinson and Ayanaba, 1977). The dry matter decline was faster in the single layer compared to double layer top, which was faster than the double layer bottom.

The addition of inorganic N fertilizer only affected the decomposition of EFB placed as a single layer on the ground, where the addition of 3.5 or 7.0 kg ammonium sulphate palm-l yr^{-1} did show significant difference in the rate of dry matter weight loss in EFB. The addition of inorganic N to organic materials high in C:N ratio and lignin, has been shown to increase decomposition rate of the materials, which is in agreement with past work which showed that the addition of inorganic N fertilizers accelerated the decomposition process by reducing the C:N ratio (van Vuuren and van der Eerden, 1992), due to enhance microbial activity (Parr and Papendick, 1978; Jantzen and Ladder, 1989). However, it did not affect the decomposition rate of EFB placed in the top layer or bottom layer of the double layer treatment. The application of inorganic K fertilizers did not show any effect on dry matter loss in EFB for all treatments.

No N release was detected from the decomposing EFB. The EFB-N content remained relatively as high as its original content for all the three EFB layers studied. The addition of inorganic N and K also did not affect the EFB-N release, though the addition of N had been shown to increase mineralization and decrease immobilization of N by decomposing organic materials (White *et al.*, 1988; Priha and Smolander, 1995; Smolander *et al.*, 1995). This renders EFB an ineffective source of nutrient N for oil palm. The N concentration in the EFB increases with time as observed by the N content remaining constant while the dry matter weights decreased. This shows that the EFB-N remained tied up in the decomposing material, which is in agreement with studies carried out by Stefan and Jergen (1994) in which N accumulation (as percentage of original N) was most pronounced in materials poor in N. EFB with N content of 0.56% – 0.70% is considered poor in N content. It has been established that materials with N content below 2% (Myers *et al.*, 1994; Palm and Sanchez, 1991), 1.5% to 2% (Harmsen and van Scheven, 1955) will initially immobilize N as they decompose. EFB falls into this category, due to the low N content and is further enhanced by the high lignin content (28% – 29%), which has been implicated in the formation of nitrogen 'lignin-derivative' complexes (Melillo *et al.*, 1982) which is resistant to microbial attack. This explains the very slow loss in dry matter weight in the second phase of EFB decomposition.

The rate of EFB-K release was generally in harmony with earlier results (Rosenani and Hoe, 1996; Rosenani *et al.*, 1996) which reported rapid initial release as K is not chemically bound in the plant cellular structure and is easily eluted by rainfall (Vilela and Richey, 1985). Ideally, removal of EFB from palm oil mill and its subsequent field application should be carried out promptly to minimize the unnecessary loss of K.

CONCLUSION

The general pattern of EFB decomposition was an exponential model with rapid losses in dry matter during the initial period and a slower rate at the later months. Total physical disintegration of EFB took seven months under oil palm canopy after which time very little dry matter loss was observed. The decomposition trends showed the single layer was the fastest followed by the double layer top and double layer bottom EFB, with the single layer EFB significantly affected by the addition of inorganic N. K was the faster nutrient released by the decomposing EFB showing the importance of immediate EFB application to the oil palm fields for the K to be immediately utilized by the palms. EFB is an ineffective source of nutrient N as no N release was detected from the decomposing EFB during the 10 months of study.

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