A Lysimetric Study on the Effect of N and P Fertilizer Application on Decomposition and Nutrient Release of Oil Palm Empty Fruit Bunches

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RINGKASAN

Masakini, tandan kosong kelapa sawit (EFB), satu hasil sampingan utama perkilangan minyak sawit, digunakan semula sebagai sungkupan di ladang kelapa sawit. Satu percubaan menggunakan mini-lisimeter (55 cm garispusat dan 22 cm tinggi) telah dijalankan untuk mengkaji kesan penambahan baja N dan P ke atas pereputan EFB dan pembebasan nutrien. Mini-lisimeter diisikan dengan tanah atasan (Typic Hapludox) dari tapak percubaan dan mempunyai rawatan: kawalan (tanpa EFB), EFB sahaja, EFB bersama N (EFB+N), bersama P (EFB+P), dan EFB bersama N dan P (EFB+N+P). Setiap rawatan EFB diletakkan dua tandan kosong di atas permukaan tanah dan dibiarkan reput di bawah pohon kelapa sawit di ladang. Larutan tanah yang keluar dari lisimeter disalurkan ke dalam botol dan dianalisiskan setiap minggu.

Pada puratanya, didapati EFB yang digunakan mempunyai 18.5% selulosa, 28.9% lignin, 0.84 – 0.92% N, 0.16% P dan 2.5% K, berasaskan berat kering jisim (BKJ). Purata berat kering jisim setandan ialah 1.55 ± 0.06 kg dan nisbah C:N bernilai 89–93. Tandan kosong EFB+N mereput lebih cepat daripada rawatan-rawatan lain selepas minggu ke-6 dan mencapai 50% kehilangan BKJ dalam 11.5 minggu. Rawatan EFB+N+P mempunyai 50% kehilangan BKJ dalam 14 minggu manakala rawatan EFB sahaja dan EFB+P, masing-masing mempunyai 42% dan 47% kehilangan BKJ pada minggu ke-15. Nisbah C:N tandan kosong EFB+N menurun daripada 91.2 kepada 58.2 dan membebaskan N lebih cepat daripada rawatan lain. Pada keseluruhannya, 15.5% hingga 27.2% kandungan N EFB asal telah dibebaskan dalam 15 minggu pereputan. Pada masa yang sama, fosforus yang dibebaskan ialah 9% – 23% kandungan asal. Kalium pula dibebaskan dengan cepat semasa pereputan dalam semua rawatan, iaitu > 50% daripada kandungan asal EFB dibebaskan dalam hanya 3 minggu. Dalam 6 minggu pereputan, pembebasan K dalam rawatan EFB bersama baja N atau P atau kedua-dua N dan P lebih cepat daripada EFB tanpa baja. Hanya 5.0% – 8.8% kandungan K asal sahaja tinggal dalam tandan selepas 15 minggu pereputan. Jumlah kumulatif N tak organik dalam larutan yang keluar dari lisimeter didapati tertinggi sekali dalam rawatan EFB+N. Pereputan EFB juga menyebabkan K^+ tukarganti dalam tanah meningkat daripada 0.06 kepada 6.5 – 8.4 cmol(+)/kg tanah dan pH tanah meningkat daripada 4.5 hingga 6.4 – 7.2.

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INTRODUCTION

The oil palm empty fruit bunch (EFB) is a major by-product of the palm oil industry in Malaysia. In the palm oil milling process, one tonne of fresh fruit bunches (FFB) produces about 0.22 tonne EFB. Under the 1991 Sixth Malaysian Plan an estimated 2.5 million hectares will be planted with oil palm by the year 2000, resulting in increased amount of EFB produced. The EFB, till a few years ago, were turned into palm ash by incineration, thus polluting the environment. Fortunately, with the present stringent regulation on air pollution, most of the EFB are now used for mulching oil palms. About 20% of the FFB harvested (*i.e.* about 5 tonnes/ha out of 25 tonnes/ha yield) is returned to the oil palm field (Loong *et al.*, 1987). This means that a fifth to a sixth of an oil palm area can be maintained with minimal inorganic fertilizer if all of the EFB were returned to the field.

The EFB mulch has been found to be beneficial not only as a nutrient source but it also improves the soil structure, conserves soil moisture, reduces soil temperature and prevents soil erosion (Gurmit Singh *et al.*, 1982; Loong *et al.*, 1987). The EFB contains an average of 0.8% N, 0.1% P, 2.4% K, and 0.2% Mg on fresh weight basis (Gurmit Singh *et al.*, 1982). According to Loong *et al.* (1987), field trials had shown distinct yield response to EFB mulching of up to 55.5 tonnes/ha on an inland soil, and that supplements of P and N chemical fertilizers were found to increase the yield further. Lim and Chan (1989) had also reported from their field trials that EFB applied at the time of field planting had resulted in significantly higher FFB yields than plots without EFB. Their results also showed that addition of minimal chemical fertilizer supplements increased the vegetative growth and subsequently the yield. The maturity period was also reduced by several months when EFB were applied at the time of field planting. Currently, it is common practice for EFB to be placed in heaps on the ground in the middle of two or four mature palms in a row. These are in between alternate palm rows or in a circle at the base of newly planted palms.

Decomposition of EFB in the oil palm field has been shown to be rapid. Lim (1989) investigated the composting of EFB and found 50% loss in dry matter weight (DMW) in 12 weeks. The rate of decomposition of organic materials is influenced by several factors. One of them is the particle size of the organic material which gives the total surface area for interaction by micro-organisms. The EFB is placed on the ground in whole bunches, thus, allowing for slower and steady release of nutrients during decomposition. Lim *et al.* (1989) reported that the moisture content of the EFB reached 31% – 81% in 32 weeks. Their results further showed that percent N, Mg and Ca content of the EFB increased with time while the percent C and C:N ratio decreased, percent K increased up to the 12th week and then decreased. Investigations using mini-lysimeters in the field, however, showed 50% DMW loss in 7 – 9 weeks of decomposition of EFB placed in a single or double layers (unpublished data). Moisture is one of the main factors in influencing the decomposition rate of organic matter. Moisture of 50% – 60% (of fresh EFB weight) is most conducive for decompositon as microbial activities are highest at this level (Hoitink and Kuter, 1980). Lower or higher moisture levels reduce microbial activities. Decomposition of EFB generates heat and increases the temperature in the

heap. Thus, the microorganisms involved in EFB decomposition are mainly mesophilics (active at 30°C – 45°C) and some thermophilics (Verstraete, 1984).

Although EFB mulching is now a common practice in most oil palm plantations, greater knowledge of the decomposition process of EFB in the field is greatly needed in order to apply EFB efficiently, *i.e.* applied at the right time of palm growth at an optimum rate to synchronize mineralization of nutrients with plant uptake and requirement. It has now become a common practice in most plantations to add N and P fertilizer to EFB in order to increase yield response. Although added N fertilizer has been known to enhance EFB decomposition, understanding of the extent of the effect of these supplementary fertilizers on EFB decomposition and nutrient release is lacking. This study was conducted in an attempt to understand the effect of N and P fertilizer supplements on the decomposition of EFB applied in a single layer (EFB are normally applied in a single layer, in a circle at the base of the palm trunk). The study was carried out using mini-lysimeters which were placed under the palm canopies in the field (but without plant root activities). The main nutrients investigated in this study were N and K as EFB are applied as an important source of N and K for the oil palms. The data presented in this paper are from observations and samplings done in the first 15 weeks of decomposition and nutrient release.

MATERIALS AND METHODS

The mini-lysimeters used in this study were made from round plastic containers of 55 cm diameter and 22 cm height with a hole at the base for collection of the soil solution. They were filled with 18 cm layer of topsoil of the experimental area (*Figure 1*). The soil of this area was classified as Gajah Mati series (Typic Hapludox), with 74.5%

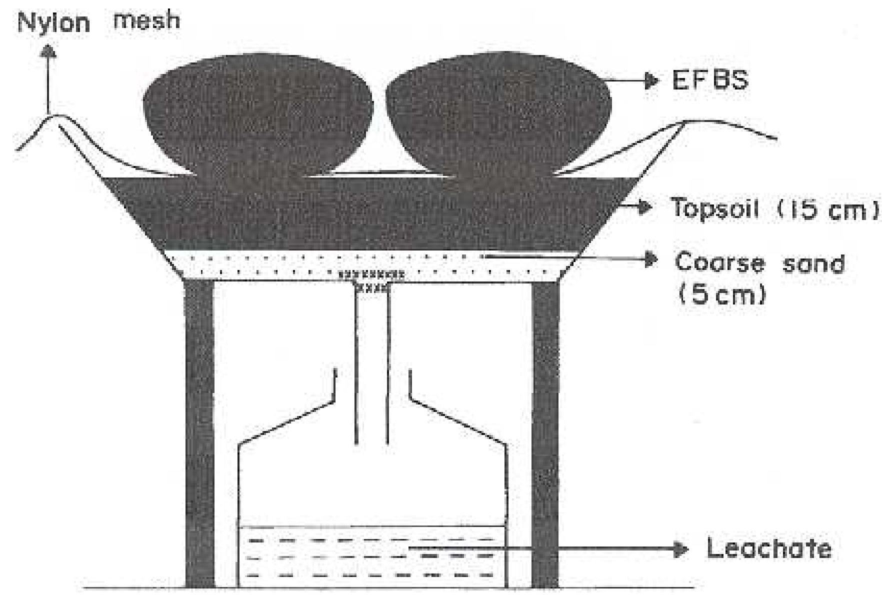

Figure 1. Schematic diagram of a mini-lysimeter filled with topsoil and 2 EFBs laid on a nylon mesh.

clay, 6.7% silt and 18.8% sand, pH 4.5, CEC of 10.1 cmol(+) kg^{-1}, 1.48% organic C and 0.15% total N. The soil surface was covered with a piece of mesh nylon netting before placing two EFB, side by side, on top of it. The treatments were: without EFB (Co), EFB alone (EFB), EFB with N fertilizer (EFB+N), EFB with P fertilizer (EFB+P) and EFB with both N and P fertilizers (EFB+N+P). The treatments were replicated four times and laid out in a completely randomized design. Similar sized EFB were used for the study. The N and P fertilizers applied onto the EFB were 50g urea and 50g triple super phosphate. They were allowed to decompose under the oil palm canopies. As the EFB decomposed, the soluble organic and inorganic constituents (nutrients) were released into the soil, depending on the precipitation. The released nutrients in the soil solution then leached out of the soil layer and collected in the bottle at the bottom of the lysimeter. These nutrients were considered available for plant uptake and also vulnerable to leaching loss.

To determine changes in DMW, C:N ratio, N, P and K content of the EFB and soil pH, small samples of the EFB tissue and soil were taken every three weeks. The total fresh weight of the EFB was recorded and the moisture content determined. The DMW of the tissue samples removed every three weeks was corrected in the calculation of the total DMW of the EFB. This was done in the following sampling time by taking into account the rate of weight loss in the 3-week period. After 15 weeks of decomposition, the soil samples were analysed for total N, mineral N, organic carbon, pH, and CEC (cation exchange capacity). Leachates that drained out of the lysimeters were collected and analysed weekly for mineral N and K.

The organic carbon content of EFB tissue was determined according to the Mebius method, and the Walkley-Black method was used for organic carbon content of soil (Nelson and Sommers, 1982). The semimicro-Kjeldahl procedure using salicylic acid to include nitrate and nitrite (Bremner and Mulvaney, 1982) was used to determine total N in the EFB tissue and soil. Potassium and P contents of the EFB were determined by ashing and dissolving in nitric acid then analysed using the Autoanalyser. The NO_3-N and NH_4-N concentrations in the leachates were determined by steam distillation and titration with hydrochloric acid (Bremner, 1965). The K concentration of the leachate was determined using flame photometer, after dilution. Soil pH was measured in a soil to water ratio of 1:2.5. The CEC and exchangeable cations were determined using the leaching method with ammonium acetate at pH 7; Ca and Mg were determined on the atomic absorption spectrophotometer and K on the flame photometer.

All statistical analyses were performed using the Statistical Analysis System (SAS 1985).

RESULTS AND DISCUSSION

The average chemical composition of the EFB used was 18.5% cellulose, 28.9% lignin, 0.84% – 0.92% N, 0.16% P and 2.5% K, dry matter weight basis. The C:N ratio was 89 – 93 and the average DMW per bunch was 1.55 ± 0.06 kg.

EFB DECOMPOSITION

Results of the percent DMW remaining and the decrease in C:N ratio of the EFB during decomposition seemed almost parallel (*Figure 2*). The DMW of the EFB dropped rapidly in the first

three weeks in all the treatments, indicating rapid decomposition in the initial stage. Initial stages of decomposition are usually dominated by mineralization of the easily decomposable fractions, *i.e.* sugars, hemicellulose and cellulose (Green *et al.*, 1995). Decomposition seemed to slow down in the period between week 3 and week 9, and then accelerated again up to week 15. The chemical composition of plant residues regulates strongly the mass-loss rates (McClaugherty and Berg, 1987) but environmental factors regulating microorganism activites are most important in influencing decomposition (mass-loss) pattern, *i.e.* soil temperature, moisture, nutrient availability and energy source availability (Kowalenco *et al.*, 1978; Parr and Papendick, 1978). The EFB+N, unlike the other treatments, seemed to decompose at almost a constant rate during the 15 week period. Addition of available N to residues has been known to accelerate initial stages of decomposition of high C:N ratio residues (Parr and Papendick, 1978; Jantzen and Ladder, 1989) due to enhanced microbial activity. Phosphorus is also immobilized to form part of the protoplasma of microorganism cells (Verstraete, 1984). In this study, however, it is unclear why decomposition in EFB+N+P seemed retarded in the first nine weeks and accelerated after that (not similar to EFB+N). This could be seen from percent DMW remaining as well as the C:N ratio. The treatment EFB+P showed the most rapid decomposition in the first three weeks, then slowed till week 15. This was probably because there was already some available N (as in other treatments) and the added P enhanced decomposition. However, N became limited after week 3 and thus decomposition slowed down as in the treatment of EFB (without N or P).

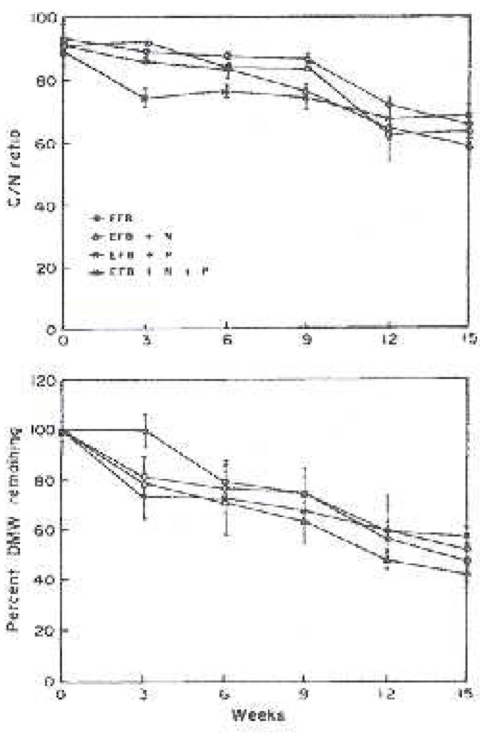

Figure 2. Changes in C:N ratio and DMW of the EFB during decomposition.

At week 15 there was statistically significant differences between treatments in the %DMW remaining ($P \leq 0.05$) and the C:N ratio ($P \leq 0.001$). The EFB+N decomposed more rapidly than the other treatments in the 15 week period; the C:N ratio dropped from 91.2 to 58.2 and only 42.0% of DMW remaining. Fifty percent weight loss was achieved in 11.5 weeks and 14 weeks for EFB+N and EFB+N+P, respectively, and > 15 weeks for EFN+P and EFB alone. Decompositon rate of the EFB could be expected to decrease later as what remained of the EFB are

the more lignified structures.

NUTRIENT RELEASE PATTERN AND AVAILABILITY IN SOIL SOLUTION

Figure 3 shows the release patterns of N, P and K content of the EFBs in the different treatments. Statistically, there was no significant difference between the treatments in the %N, %P and %K remaining at the different sampling times. This could probably be attributed to non-uniformity of chemical composition of EFB tissue samples taken. *Table 1* shows the high standard deviations in N, P and K contents of the EFB between the replicates within the treatments.

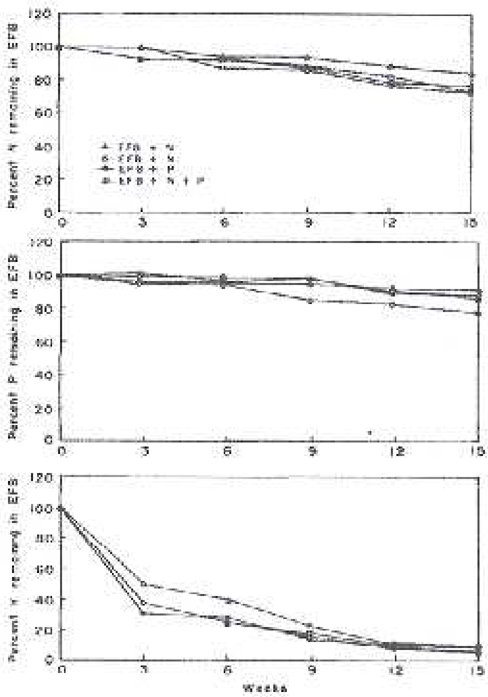

Figure 3. Percent N, P and K remaining in the EFB tissue during decomposition.

In general, *Figure 3(a)* shows a faster N release after week 3 for EFB+N and week 6 for EFB+N+P and EFB+P. A very slow rate of N release was observed in the EFB treatment. This was, obviously, due to its slow rate of decomposition and mineralization, compared to the other treatments. After 15 weeks of decomposition, there were only 15.6%, 23.5%, 27.2% and 27.8% of initial EFB-N content released from the treatments EFB, EFB+P, EFB+N+P and EFB+N, respectively. Accelerated N mineralization of organic matter often occurs with fertilization. Jantzen and Radder (1989) observed highest mineralization in cereal grain crop receiving fertilizers. *Figure 4(a)* shows the amounts of mineral N (NO_3-N, NO_2-N and NH_4-N) available in the soil solution as a result of N released from the two EFB in each treatment. There were very small amounts of mineral N in the soil solution in the first two weeks due to the low precipitation during this period. Thereafter, there seemed to be a steady rate of N release into the soil solution up to week 11. At week 12, the amounts of mineral N increased greatly; the highest precipitation was recorded in this week (*Figure 4(c)*). This indicates that high precipitation would cause leaching of N mineralized from decomposing EFB. There was significant difference ($P \leq 0.001$) between the treatments in the cumulative amounts of mineral N in the soil solutions collected in the 15-week period. There were higher cumulative amounts of N in the EFB+N and EFB+N+P than the EFB+P and EFB treatments. This coincided with the slightly higher amounts of N released from the former treatments. The cumulative amount of mineral N at

TABLE 1. CHANGES IN DRY MATTER WEIGHT (DMW) AND TOTAL N, P AND K CONTENT OF EFB (per bunch basis) DURING DECOMPOSITION

Weeks of Decomposition	DMW (kg)				N (g)			
	EFB	EFB+N	EFB+P	EFB+N+P	EFB	EFB+N	EFB+P	EFB+N+P
0	1.55 ± 0.06	1.55 + 0.06	1.55 ± 0.06	1.56 ± 0.06	13.5 ± 1.3	13.8 ± 1.5	14.2 ± 1.0	13.8 ± 5.2
3	1.26 ± 0.07	1.22 ± 0.12	1.14 ± 0.14	1.27 ± 0.08	13.4 ± 3.5	13.0 ± 0.3	13.1 ± 2.2	12.9 ± 1.4
6	1.19 ± 0.08	1.10 ± 0.07	1.13 ± 0.17	1.23 ± 0.08	12.7 ± 1.0	12.1 ± 1.2	13.1 ± 1.0	12.8 ± 1.1
9	1.16 ± 0.14	0.98 + 0.08	1.05 ± 0.13	1.16 ± 0.09	12.6 ± 0.5	11.9 ± 0.5	12.4 + 0.7	12.2 ± 2.7
12	0.93 ± 0.16	0.74 ± 0.04	0.92 ± 0.17	0.87 ± 0.11	11.9 ± 1.1	10.6 ± 0.7	11.1 ± 0.3	11.4 ± 1.6
15	0.80 ± 0.09	0.65 ± 0.05	0.88 + 0.06	0.73 ± 0.10	11.4 ± 1.6	10.0 ± 1.0	10.9 ± 2.3	10.0 ± 0.7

Weeks of Decomposition	K (g)				P (g)			
	EFB	EFB+N	EFB+P	EFB+N+P	EFB	EFB+N	EFB+P	EFB+N+P
0	38.6 ± 4.2	38.9 ± 1.1	38.8 ± 5.0	38.0 ± 12.9	2.5 ± 0.3	2.5 ± 0.6	2.4 ± 0.5	2.5 ± 1.4
3	19.2 ± 7.3	14.6 ± 9.4	11.5 ± 7.4	14.6 ± 1.6	2.4 ± 2.0	2.6 ± 1.4	2.4 ± 1.2	2.3 ± 0.7
6	15.4 ± 3.2	10.1 ± 2.5	10.8 + 1.2	9.6 ± 1.1	2.4 ± 0.9	2.3 ± 1.0	2.3 ± 1.0	2.6 ± 1.5
9	8.7 ± 2.8	6.00 ± 1.5	5.3 ± 0.5	6.8 ± 0.7	2.4 ± 1.1	2.1 ± 1.1	2.4 ± 0.5	2.5 ± 0.5
12	4.3 ± 1.6	2.9 ± 0.3	3.8 ± 1.4	3.5 ± 2.0	2.3 ± 1.6	3.0 ± 1.1	2.1 + 0.8	2.3 ± 0.8
15	3.4 ± 1.1	2.0 ± 0.8	3.2 ± 0.3	1.9 ± 0.8	2.3 ± 1.5	2.0 ± 1.5	2.1 ± 1.0	2.2 ± 1.4

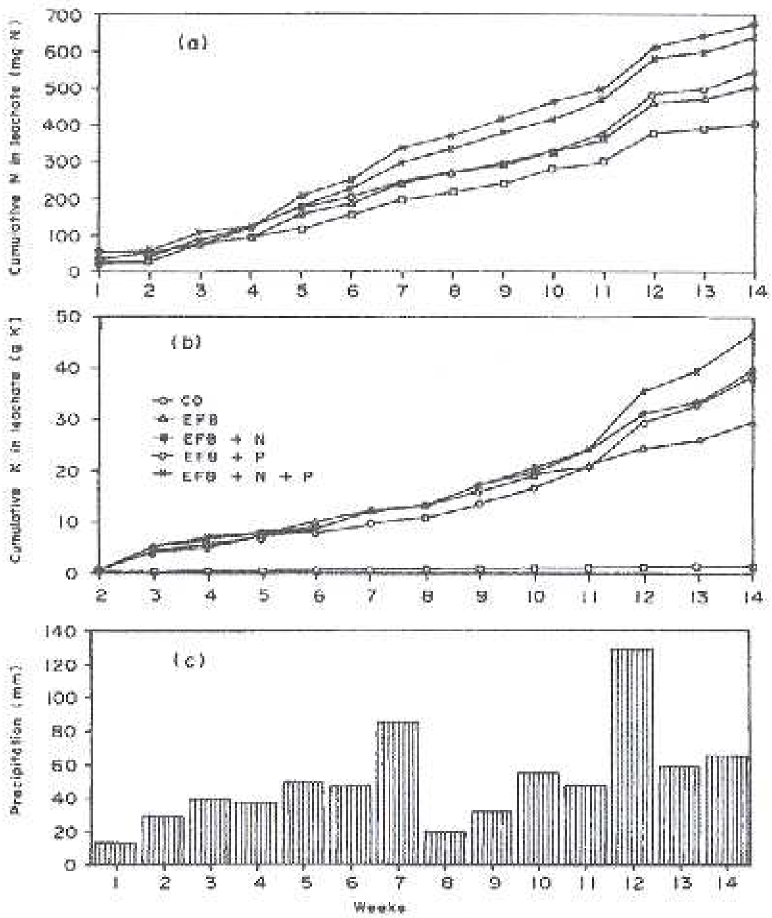

Figure 4. Cumulative amounts of mineral N and K in the leachates collected during the EFB decomposition and precipitation.

week 15, however, was only a small percentage of the total amount of N released from the EFB. The remainder of the N released could partly be in the soluble organic forms in the solution (apart from immobilization by microorganisms in the soil, fixation in clays and loss through denitrification and/or ammonia volatilization).

Phosphorus release pattern from the decomposing EFB was similar to N release. However, less P was released than N probably due to the lower EFB-P content (*Figure 3*). At week 15, the P released was 8.9% – 22.6%; highest P release came from EFB+N. Phoshorus immobilization, like N, is expected in plant residues with high C:P ratio and 0.3% P content (Singh and Jones, 1976).

Potassium release from EFB was very rapid in the first three weeks in all the treatments; 50.4% – 69.7% of initial EFB-K content was released (*Figure 3(c)*). Potassium released from the EFB (without N or P) treatment seemed slower than the other treatments. At week 15, however, no significant difference was observed between the treatments; only 5.0% – 8.8% K remaining in the EFB. The K released from the decomposing EFB resulted in high amounts of K in the soil solution

TABLE 2. EFFECT OF EFB TREATMENT ON THE CHEMICAL SOIL PROPERTIES AFTER 15 WEEKS OF DECOMPOSITION

Soil Properties	Week 0	Week 15					
		Co	EFB	EFB+N	EFB+P	EFB+N+P	LSD (P = 0.05)
CEC cmol (+) kg^{-1}	10.03	9.09	10.35	12.32	10.66	11.02	n.s
Exch. Ca^{2+} cmol (+) kg^{-1}	0.08	0.06	0.19	0.20	0.17	0.18	0.08
Exch. M^{2+} cmol (+) kg^{-1}	0.05	0.03	0.70	1.14	1.25	1.740	0.21
Exch. K^{+} cmol (+) kg^{-1}	0.06	0.05	6.53	7.92	8.39	7.12	1.41
pH	4.5	4.4	6.4	7.2	7.0	6.9	0.91
% Organic C	1.48	1.24	1.52	1.50	1.58	1.56	n.s
% Tetal N	0.15	0.12	0.17	0.19	0.18	0.18	n.s
C:N	9.87	10.33	8.94	7.89	8.78	8.67	n.s

n.s. – means are not significant

(*Figure 4(b)*) and an increase in exchangeable K in the soil (*Table 2*). Unlike N and P, the amount of K released at any particular time is greatly influenced by rainfall intensity. Tian *et al.* (1992) observed rapid K release in all the plant residues they had tested; most of the K was released in < 41 days. They reported that K release was less affected by chemical characteristics of the plant residues and fauna activities than N and P. Due to its high mobility, it is easily leached out of the plant residues.

EFFECT OF EFB DECOMPOSITION ON THE SOIL CHEMICAL CHARACTERISTICS

In the short period of 15 weeks of EFB decomposition (in the absence of root activity), there was an increase in soil pH from 4.5 to 6.4 – 7.2 (*Table 2*). It has been recorded that the pH of soils under oil palm with EFB mulching increased by one unit (Lim, personal comm.). All the EFB treatments significantly increased the availability of K, Ca and Mg in soils over the control (soil without EFB, N and P fertilizer supplements). It has been reported that green manuring resulted in increased availability of K (Swarp, 1987) and Ca and Mg (Khind *et al.*, 1987) in soils.

CONCLUSION

Decomposition of EFB was accelerated in treatments EFB+N and EFB+N+P, with 50% DMW loss at about 11.5 weeks and 14.0 weeks, respectively, compared to > 15 weeks for EFB+P and EFB alone. However, there was no significant difference between treatments in the nutrient release pattern. In general K was rapidly released in the treatments with EFB, with only 5.0% – 8.8% K remaining after 15 weeks of decomposition.

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