Dynamics of Nutrient Release from Empty Fruit Bunches in Field Conditions and Soil Characteristics Changes

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Every tonne of crude palm oil produced generates by way of by-product, one tonne of empty fruit bunches (EFB). In the last decade an increasing number of planters have been considering the utilization of EFB as a means of reducing mineral fertilizer inputs while improving soil fertility. Indeed, in the recent past, several studies have demonstrate the positive impact of EFB application on oil palm mineral nutrition and palm performance during both immature and mature periods. As a result, general agricultural policies have been issued.

In order to optimise the use of EFB in any situation (*e.g.* various soil types and climatic patterns) without necessarily setting up extensive and long term field trials, a tentative modelling of the dynamics of mineralization and kinetics of release of the nutrients from EFB applied in the field has been initiated. A specific experiment has been established for that purpose. The protocol and objectives are described.

The results obtained show that it is possible as a first step to devise a simple mathematical model for the evolution of EFB through several parameters: mineralization, N, P, K and Mg release. These models are used to computerize the nutritional value of EFB (expressed as fertilizers equivalents) at any time after their application in the field, and to simulate the amount of nutrients received by the soil. A good indicator of the speed of release of each nutrient is the "Released 50", time when 50% of the initial amount of nutrient contained in EFB has been released. N, P, K and Mg "Release 50" are respectively 205, 85, 25 and 115 days after application. Almost the entire potassium content is released within only three months. The use of more mechanistic models is discussed in order to explain differences between nutrients.

Simultaneously, changes in soil chemical and physical properties have been monitored for more than two years. Results show tremendous modifications of chemical characteristics. An application of 60 t/ha of EFB results in a progressive increase of K exchangeable down to a depth of 0.80 m. The amount of K exch. increases up to 20 times three months after EFB application. Similar results are found for Mg and, to a lesser extent for Ca, with different patterns. These two nutrients remain in the top layers of soil. Losses of nutrients through leaching appear to be very limited.

Another dramatic change concerns the soil pH. In the upper layers of soil, pH increases from an initial 4.5 up to 7, two months after EFB application. This could be explained by significant variations of exchangeable aluminium and calcium in soil measured during the experiment. This positive impact reaches progressively 0.40-0.60 m depth.

Beside these chemical properties changes, an improvement of soil permeability has also been observed.

Based on these results it becomes possible to review current agricultural

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policies in order to adjust the rate and frequency of EFB applications according to soil type and rainfall pattern.

For each tonne of palm oil produced, around one tonne of EFB, considered as waste, have to be disposed. Such large quantities of EFB were once a considerable constraint and were usually incinerated. The ash was then spread in the estates to take advantage of the relatively high potassium content as a replacement for commercial potassium fertilizers (Sadi *et al.*, 1992).

Environmental concerns have led to incineration being banned in most recent crop development projects. A few composting units have been set up, but fresh EFB are usually spread directly in the field (Loong *et al.*, 1987; Lim and Chan, 1989; Sing *et al.*, 1989; Hornus *et al.*, 1992; Sadi *et al.*, 1992). Farmers thereby benefit from the fertilizing value of this by-product, which is easily quantifiable (*Table 1*). This application of organic matter offers benefits in the longer term for the physical-chemical properties of the soil, and more generally for soil fertility, even though only a few data are available for assessment.

TABLE 1. EFB MANURING VALUE (KG OF FERTILISER/TONNE OF EFB)

Fertiliser	Equivalence (kg)
Urea	6.1
Triple Super Phosphate	1.7
Potassium Chlorine (MOP)	16.3
Kieserite	3.0

1.5 kg of ash for 1.0 kg of KCl titrating 60% of K_2O, sometimes supplemented with 2 kg of ash to take into account variability in water and potassium content.
Application of 60 tonnes of EFB every 2 years in a continuous single layer.

Agricultural practices have been based on the results of field trials, through which it has been possible to recommend application rates giving a level of oil palm mineral nutrition in line with production objectives.

However, optimisation of EFB use requires better knowledge of the dynamics of organic matter mineralization and the release of mineral nutrients depending on climatic conditions (rainfall, temperature, etc.).

An initial trial was set up under true application conditions in the field, arranged so as to enable a study of the phenomena involved. EFB were placed in the interrows of plantings after prior characterization (individual weight, average water and mineral nutrient contents of the batch) and separated inside wide-meshed plastic nets. At more or less regular intervals (from a few days to a few weeks depending on rainfall), the EFB were taken and analysed in the laboratory to determine the kinetics of mineral nutrient release and matter reduction. At the same time, analyses of the soil beneath the EFB were also carried out at different depths, to monitor changes in chemical properties.

Infiltrometry measurements have also been programmed to try and characterize the impact on the physical properties of soils.

DYNAMICS OF MINERAL NUTRIENT RELEASE FROM EFB

Figures 1 to *3* shows EFB mineralization dynamics and release of the main mineral nutrients (N-P-K-Mg). In an initial approach, simple mathematical functions were adjusted so as to facilitate interpolations for calculating the fertilizing capacity of EFB over time after their application (*Table 2*). Rainfall recorded over open land (above the canopy) is also indicated.

Weight loss from the EFB was very rapid in the first month, with a reduction of almost 50% (*Figure 1*). It continued thereafter at a more modest rate: eleven months after EFB application, there only remained 14% of the initial weight. Application of nitrogen to

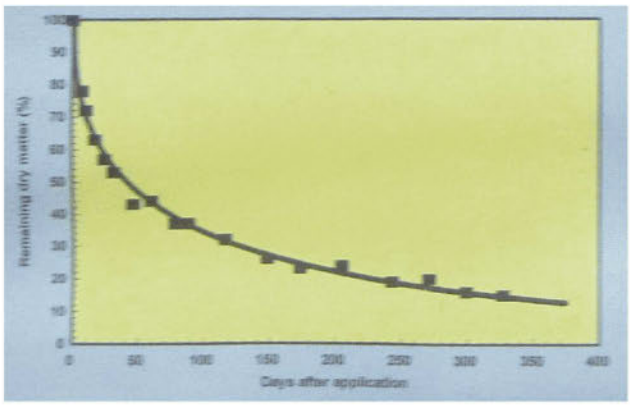

Figure 1. Kinetics of EFB mineralisation after field application.

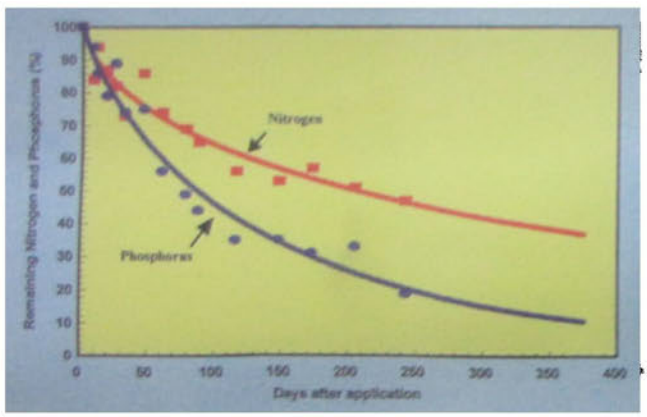

Figure 2. Dynamic of N and P release from EFB after field application.

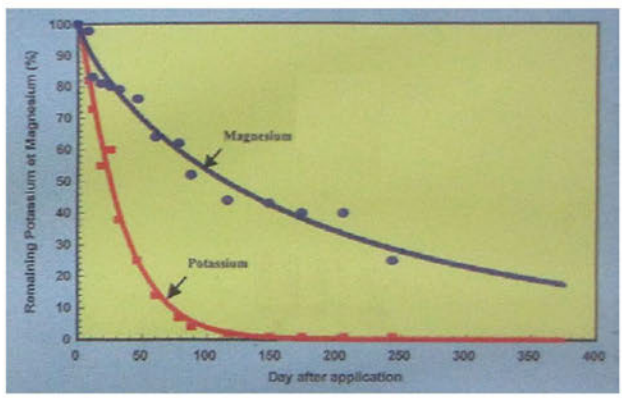

Figure 3. Dynamic of K and Mg release from EFB after field application.

the EFB at the time they were spread (3 kg of urea per tonne of EFB) accelerated the process by almost 30% in the first ten days. This effect dropped to 25% then 20% in the following months. Application of phosphate (2.25 kg of Triple Super Phosphate) also accelerated the mineralization process, but only in the first three months.

For mineral nutrients, the most notable result is the rapidity with which potassium, the major content of EFB, is released: one week after application in the field, 18% of the potassium was released, whilst 33 mm of rainfall (2 showers) were recorded (*Figure 3*). Three months after the start of the trial, there was virtually no more potassium in the EFB.

Phosphorus and magnesium dynamics were much slower and seemed to follow relatively similar kinetics (*Figures 2* and *3*). Nitrogen release was similar to that of magnesium in the first month, then it slowed down: eleven months after application, there still remained 40% of nitrogen in the EFB.

The release time for 50% of the mineral nutrients seems to be a good indicator of the different kinetics observed (*Table 3*).

Change in the physical-chemical properties of the soils

The above events occurring at the soil surface have a major impact on the physical-chemical properties of the soil.

Exchangeable potassium contents, which were initially very low (under 0.05 meq throughout the profile) were considerably increased by these ongoing supplies. These developments logically affected the surface horizons, then moved down: 0.40 m after a month, 0.80 m after 2-3 months (*Figure 4*).

In addition, measurements taken deep down (1.40m-1.50m) did not seem to indicate losses through leaching.

When calculating variations in assimilable potassium over time totalised over a depth of one metre (zone intensively explored by the root system), a gradual increase was seen, reaching 20 times the initial K three months after applications, in accordance with the release kinetics for this nutrient. Eighteen months after the start of the trial, there existed eight times more exchangeable potassium compared to the outset. This potassium was then primarily in the 0.15-0.80 m horizon.

For exchangeable magnesium, only the 0-0.15 m surface horizons (primarily) underwent profound changes (*Figure 5*). Calcium seemed to be even less mobile, remaining in the first five centimetres of soil. Magnesium and calcium, which are bivalent ions, are in fact generally more effectively held than monovalent ions such as potassium by organic matter, which was more abundant in these surface horizons.

Whilst the set of analyses carried out did not reveal any significant variation in nitrogen and carbon contents, the pH profile was considerably disrupted. From an acid profile at the beginning of the trial (pH= 4.5 on the surface to 5.1-0.80 m deep down), the pH increased very quickly on the surface, reaching neutral two months after the EFB were spread (*Figure 6*). This effect then spread downwards with less intensity (pH= 5.4 to 0.60 m after nine months). A return to more acid pH values began after six months for the upper horizon, later deeper down.

Opposing variations were recorded for exchangeable aluminium, which must undoubtedly have precipitated when the pH became higher than 5.5.

The first observations regarding the physical properties of the soil consisted in permeability measurements, comparing a control site that had never received any EFB with a site where applications had been

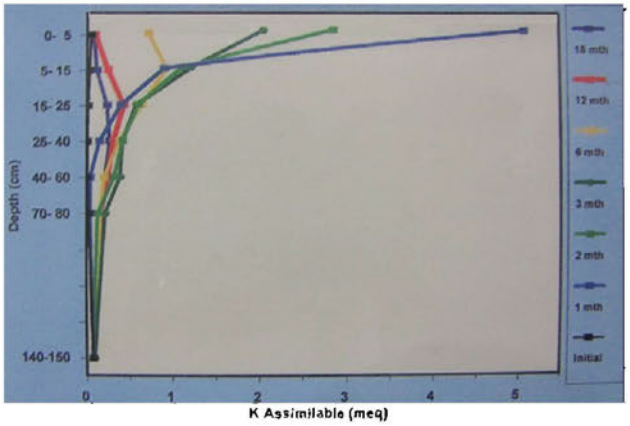

Figure 4. Variation in exchangeable K in the soil after EFB application.

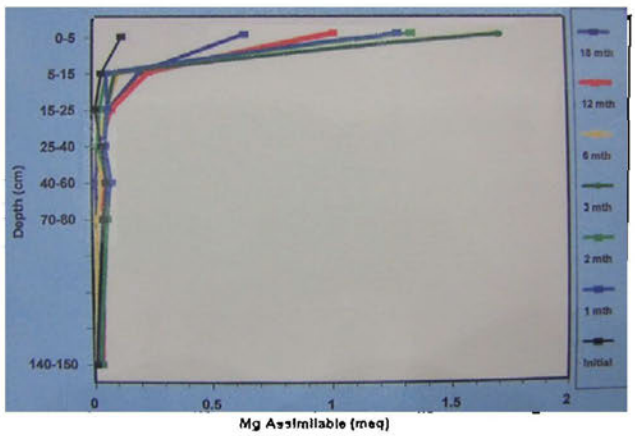

Figure 5. Variation in Exchangeable Mg in the soil after EFB application.

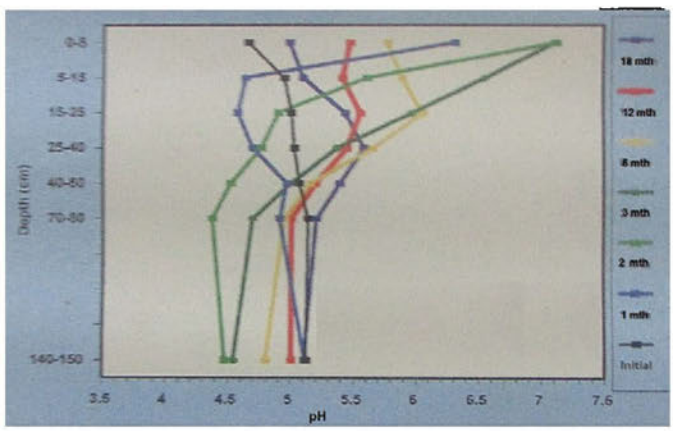

Figure 6. Variation in soil pH after EFB application.

TABLE 2. EFB MANURING VALUE: EQUIVALENT FERTILISER RELEASED WITH TIME

Time after field application	Rainfall (mm)	Equivalent Urea (Kg/palm)	Equivalent TSP (Kg/palm)	Equivalent KCl (Kg/palm)	Equivalent Kieserite (Kg/palm)
		(1)	(2)		
T0 (initial content)	-	**2.60**	**0.725**	**6.80**	**1.250**
1 week	33	0.235	0.070	1.225	0.100
2 weeks	50	0.105	0.035	0.885	0.060
3 weeks	93	0.050	0.015	0.545	0.025
4 weeks	123	0.050	0.045	0.815	0.050
2 month	428	0.285	0.125	2.310	0.190
3 month	676	0.155	0.070	0.610	0.125
6 month	1540	0.310	0.145	0.340	0.235
9 month	2287	0.260	0.085	-	0.150
11 month	2605	0.105	0.035	-	0.060

(1): without nitrogen application on top of EFB
(2): without phosphate application on top of EFB

TABLE 3. RELEASE TIME FOR 50% NUTRIENT (DAY).

N (1)	P (2)	K	Mg	Dry matter Weight
205	85	25	115	40

(1) = without nitrogen application on top of EFB
(2) = without phosphate application on top of EFB

carried out two years earlier. The initial results indicated much lower permeability at the control site, be it at the start of measurements or during stabilization of the infiltration rate (*Table 4* and *Figure 7*).

All these phenomena could go some way to explaining the good performance of oil palms generally seen after EFB application, despite the apparent arithmetic imbalance in mineral nutrients (K and Mg) supplied.

The speed with which these nutrients are released prompts the following recommendations:

- halt mineral fertilizer applications (potash and kieserite) as soon as EFB are spread,
- apply EFB in the field as soon as they leave the mill, so as to avoid any losses through leaching (notably K), which might occur during storage, even temporary, in an open area unprotected from the climate.

The persistence of the improvement in exchangeable K and Mg contents in the soil indicates that, at the doses tested, applications every two years ensure generally satisfactory mineral nutrition for the oil palms. Nevertheless, routine monitoring of the nutritional status of the palms is recommended.

Studies and analyses are continuing, with three main aims:

- try to acquire a deeper understanding of the phenomena involved, so as to

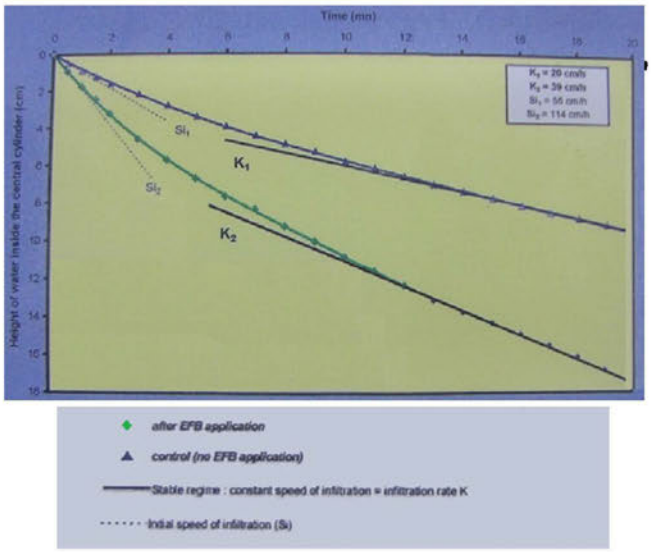

Figure 7. Impact of EFB application on soil permeability.

TABLE 4. COEFFICIENT OF PERMEABILITY K (cm/h)

Time (mn)	Control	EFB
T 0 mn	55	114
T 15 mn	20	39

enable modelling for simulations applicable to other situations. Analyses are under way using models with compartments characterized by different release speeds. Initial indications are that potassium could be totally "contained" within a single compartment, whereas the other nutrients (N, P, Mg) seem to be divided between at least two compartments,

- launch new observations with different climatic conditions (primarily rainfall), in order to construct relevant models irrespective of the application season,
- work on a complete mineral nutrient cycle: EFB – soil – plant.

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