EMPTY FRUIT BUNCH APPLICATION AND OIL PALM ROOT PROLIFERATION

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ABSTRACT

The benefits derived from the application of empty fruit bunches (EFB) included better yields and improved palm nutrient status. These benefits were the result of better soil conditions after applying EFB. Root proliferation resulting from EFB application was observed to be an important factor that led to the better yields and palm nutrient status. The study was conducted on three-year-old DxP palms. Treatments followed an arrangement for the paired t-test with one side of the palm receiving EFB (treatment) at 100 kg per palm while no EFB was applied to the other side of the same palm (which acted as the control). Root samples were collected at three and six months after EFB application. The root masses from both treatment and control were then analysed as a total of all root orders, and also according to each root order, i.e. *primary, secondary and tertiary. Comparison of quaternary roots was made using density/unit tertiary root length. Results showed that there was a proliferation of roots at a depth of 30-45 cm three months after EFB were applied. This proliferation occurred in a soil environment which was significantly improved ($p<0.05$) in terms of total and exchangeable K and total Ca at 15-45 cm soil depth. Significant ($p<0.05$) improvements in soil pH, soil moisture and P at 0-15 cm soil depth may also have influenced this proliferation of roots. It is postulated that the increased root mass under improved soil conditions implies an enhanced nutrient uptake process which explains the increased yields and better nutrient status.*

Keywords: empty fruit bunches, oil palm roots, root proliferation, plant nutrients.

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INTRODUCTION

Over the past two decades, various researchers have found that the application of empty fruit bunches (EFB) raises oil palm yield (Gurmit *et al.*, 1981; 1999; Loong *et al.*, 1987; Lim and Chan, 1989; Lim, 1998). The reason for the increased yields was attributed to 'better' soil conditions. In this article, it will be shown how the proliferation of roots under specifically improved soil conditions after applying EFB could explain the improved yields and nutrient status of the palm.

EFB are an organic substrate; a by-product of the oil palm fruit bunches that are harvested and processed. Current plantation practice is to return these EFB as mulch in the estate. It is commonly acknowledged that in areas where organic materials *e.g.* EFB or cut oil palm fronds are placed, oil palm roots proliferate. Studies by Khairuman (1998) showed that oil palm roots proliferate under oil palm frond piles. In addition to the higher root mass, Zaharah *et al.* (1989) showed that root activity was higher under the frond piles compared to that in the harvester's paths. These observations were made with the perception that the soil conditions had improved.

Gurmit *et al.* (1981) and Lim (1998) have shown that application of EFB changes some aspects of the soil chemistry but it was Zaharah and Wirkom (1999)

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who described in more detail how the decomposition of EFB relate to the chemical changes in the soil. Both workers however stopped short of quantifying these changes in the soil in relation to the proliferation of oil palm roots. Understanding the relationship between changes in the soil and the development of oil palm roots is most important because the root is the only palm organ in the soil by which nutrients are absorbed. It is therefore likely that the link between higher yield and EFB application lies in the development of roots that are active in acquiring nutrients and water, and are triggered by chemical changes in the soil.

The objective of the experiment described in this article therefore was to determine the effect of EFB on oil palm root proliferation over time.

MATERIALS AND METHODS

The experiment was carried out using three-year-old DxP palms at Field 2002A, Labu Estate, in Negeri Sembilan. The area has a gentle slope of about 7º, which was taken into consideration when locating the treatment. The soil in the area is of the Rengam series (Typic Kandiudult). Palms were fertilized with 0.31 kg N palm^{-1} yr^{-1} as ammonium sulphate, 0.9 kg K palm^{-1} yr^{-1} as muriate of potash and 0.34 kg P palm^{-1} yr^{-1} as rock phosphate. EFB were added onto the side of the palms where the land elevation was higher. EFB were also applied in between palms (*Figure 1*) so that the frond piles next to the palm would impact equally on both EFB and zero-EFB treatments. EFB used had 0.8% N, 0.01% P, 2.41% K, 0.18% Mg and 0.18% Ca.

In the experiment, one layer of EFB (+EFB) equivalent to 100 kg palm^{-1} was applied onto the soil surface covering an area 1.3 m wide and 2 m long. EFB was placed at a distance of about 1 m from the palm base. On the opposite side of the same palm, an area of similar dimensions was marked out. No EFB was applied in this area, and thus became the control (-EFB). The treatments, replicated five times, were arranged in a completely randomized design (CRD) with split plots for time of sampling, and the data collected were analysed as a paired t-test.

To determine the effects of EFB or its absence on soil chemical properties and the proliferation of oil palm roots, samples of soil and roots were collected using a specially designed soil auger shown in *Figure 2*. To facilitate two collections of samples at three and six months, each treatment area was divided into two equal sections measuring 1.3 m x 1 m. The first sample was collected from the centre of one section leaving the other section undisturbed. First sampling was made at three months after application of EFB, and the second samples were collected from the centre of the undisturbed section three months later.

Roots and soil samples were collected at three soil depths, *i.e.* at 0-15, 15-30 and 30-45 cm. For each sample, the roots were manually separated from the soil. The various root orders were identified based on the criteria set by Goh and Samsudin (1993). The weight of the soil mass, which was air-dried, and wet weights of the various root orders were then determined. The soil was analysed for pH, soil carbon, N, P, K Mg, Ca, B and cation exchange capacity (CEC). The roots were oven-dried at 70ºC for 72 hr and weighed again. The root mass (which

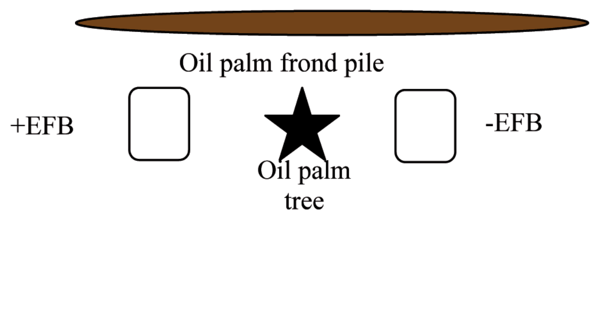

Figure 1. Position of +empty fruit bunches (EFB) and –EFB treatments in relation to the oil palm tree and oil palm frond pile.

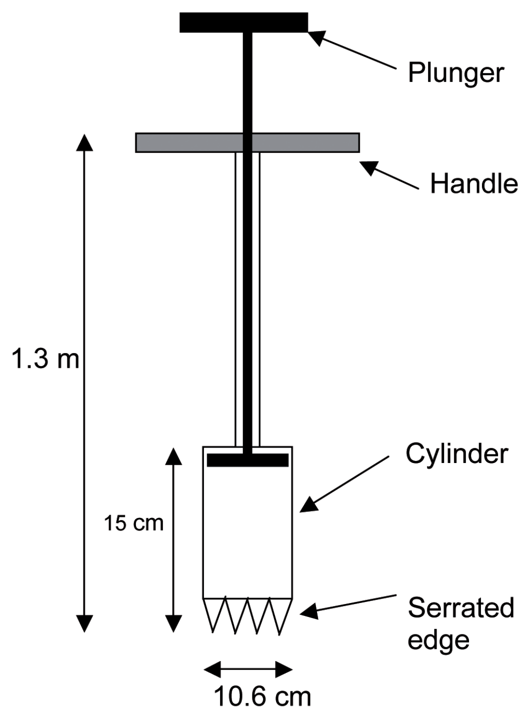

Figure 2. Specially designed soil auger for sampling oil palm roots.

was oven-dried) when divided by the soil mass (that was air-dried) gave the root mass per unit mass of soil. Soil analyses were only carried out on samples collected at three months from the commencement of trial.

The effects of the treatments on quaternary roots were observed only at the 0-15 cm soil depth as this is the depth where most of the quaternary roots are found. In the case of quaternary roots, root density was used instead of mass to determine the effects of treatments on their proliferation. To determine this, first a tertiary root was sampled and its length measured. The number of quaternary roots attached to the tertiary root was then counted. The density of the quaternary roots is therefore the number of quaternary roots divided by the length of the tertiary root. Five samples were taken for each treatment.

RESULTS

Impact of EFB on Root Mass at Three and Six Months

Application of EFB was observed to stimulate the development of total root mass, particularly at the 30-45 cm depth three months after application of EFB (*Table 1*). There were significantly more roots at this depth for the EFB-treated area compared to the zero-EFB area. The roots at the EFB-treated area were a combination of all the root orders, *i.e.* primary, secondary, tertiary and quaternary, with an average weight of 0.147 g / 100 g soil. A comparison of the masses of individual root orders shows that the individual root orders were not affected by the EFB treatment, *i.e.* there was no significant difference ($\alpha = 0.05$) in the weights of the various root orders between EFB-treated and zero-EFB soils (*Table 2*).

TABLE 1. MEAN ROOT MASS (g/100 g soil) AT VARIOUS SOIL DEPTHS AT THREE AND SIX MONTHS AFTER APPLICATION OF TREATMENTS (with and without EFB)

Soil depth (cm)	Treatment	Time (months)	
		3	6
0-15	+EFB	0.055 ± 0.019a	0.048 ± 0.029a
	-EFB	0.083 ± 0.025a	0.036 ± 0.006a
15-30	+EFB	0.113 ± 0.004a	0.072 ± 0.017a
	-EFB	0.119 ± 0.027a	0.195 ± 0.075a
30-45	+EFB	0.147 ± 0.024a	0.054 ± 0.026a
	-EFB	0.072 ± 0.017b	0.026 ± 0.010a

Note: Means (+ S.E.) of treatments at various soil depths followed by the same letter are not significantly different from one another at $\alpha = 0.05$.
EFB – empty fruit bunches.

TABLE 2. PROLIFERATION OF THREE ROOT ORDERS AT VARIOUS SOIL DEPTHS THREE MONTHS AFTER APPLICATION OF TREATMENTS

Depth (cm)	Treatment	1° root	2° root	3° (+ 4°) root
		---------Mean root mass/100 g soil---------		
0-15	+EFB	0	0.03 ± 0.01a	0.027 ± 0.007a
	-EFB	0	0.04 ± 0.01a	0.042 ± 0.017a
15-30	+EFB	0.06 ± 0.03a	0.04 ± 0.01a	0.009 ± 0.004a
	-EFB	0.08 ± 0.02a	0.03 ± 0.01a	0.005 ± 0.001a
30-45	+EFB	0.08 ± 0.03a	0.05 ± 0.04a	0.006 ± 0.002a
	-EFB	0.04 ± 0.01a	0.03 ± 0.01a	0.005 ± 0.002a

Note: Means (+ S.E.) of treatments at various soil depths for each root order followed by the same letter are not significantly different from one another at $\alpha = 0.05$.
EFB – empty fruit bunches.

Also, no significant difference in density of the quaternary roots for both treatments was observed over the three- and six-month periods at the 0-15 cm soil horizon (*Table 3*).

TABLE 3. EFFECT OF EMPTY FRUIT BUNCHES (EFB) ON MEAN DENSITY (+ S.E.) OF QUATERNARY ROOTS (number of 4° roots per cm of 3° root)

Treatment	3 months	6 months
+EFB	3.7 ± 0.3a	5.7 ± 0.3a
-EFB	3.8 ± 0.4a	6.9 ± 0.4a

Note: Means within the same column with the same letter are not significantly different from one another at α = 0.05.

Impact of EFB on Soil Chemical Properties at Three Months

There was a significant increase (α = 0.05) in soil pH and moisture at the 0-30 cm and 0-15 cm depths, respectively (*Table 4*), due to application of EFB. However, there was no significant change (α = 0.05) in organic carbon or CEC (*Table 4*). Total and available P at the 0-15 cm depth were also significantly increased (α = 0.05) for the EFB-treated plots (*Table 5*). However, there was no change in total N (*Table 5*). In addition, total and exchangeable K and total Ca were significantly increased (α = 0.05) deeper down the soil profile from 15-45 cm (*Table 6*) where EFB had been applied. However, there was no significant change in exchangeable Ca (*Table 6*), and in total and exchangeable Mg (*Table 7*) compared to the control.

DISCUSSION

Significant increases (α = 0.05) in total root mass (all orders) at the 30-45 cm horizon were observed when the soil was treated with EFB. There were also significant (α = 0.05) increases in K and Ca at this depth. Thus, it is postulated that the increased root mass could have been due to improved soil nutrient

TABLE 4. CHEMICAL PROPERTIES AT VARIOUS SOIL DEPTHS WITH AND WITHOUT EMPTY FRUIT BUNCHES (EFB) THREE MONTHS FROM COMMENCEMENT OF TRIAL

Soil depth (cm)	Treatment	Soil pH	C.E.C (cmol kg^{-1} soil)	Organic C	Water
				-------------- (%)	------------
0-15	+EFB	4.80 ± 0.15a	6.85 ± 0.79a	1.49 ± 0.10a	28.74 ± 2.95a
	-EFB	4.14 ±0.09b	7.05 ± 0.47a	1.63 ± 0.06a	21.12 ± 1.20b
15-30	+EFB	4.34 ± 0.07a	5.97 ± 0.25a	1.08 ± 0.12a	23.66 ± 0.72a
	-EFB	3.88 ± 0.13b	6.30 ± 0.23a	1.22 ± 0.05a	24.03 ± 0.82a
30-45	+EFB	4.06 ± 0.10a	5.41 ± 0.33a	0.86 ± 0.11a	24.31 ± 0.99a
	-EFB	3.86 ± 0.10a	4.90 ± 0.13a	0.65 ± 0.05a	25.19 ± 0.78a

Note: Means (+ S.E.) of treatments within the same column and soil depth with the same letter are not significantly different from one another at α = 0.05.

TABLE 5. NUTRIENT STATUS AT VARIOUS SOIL DEPTHS WITH AND WITHOUT EMPTY FRUIT BUNCHES (EFB) THREE MONTHS FROM COMMENCEMENT OF TRIAL

Soil depth (cm)	Treatment	Total N (%)	Total P	Available P
			----------------($mg\ kg^{-1}$)	---------------
0-15	+EFB	0.18 ± 0.04a	901.80 ± 118a	96.70 ± 57.60a
	-EFB	0.13 ± 0.01a	615.60 ± 49b	57.60 ± 15.30b
15-30	+EFB	0.09 ± 0.01a	700.20 ± 118a	38.08 ± 4.20a
	-EFB	0.10 ± 0.01a	490.80 ± 23a	31.16 ± 2.80a
30-45	+EFB	0.07 ± 0.01a	490.00 ± 64a	31.34 ± 5.10a
	-EFB	0.06 ± 0.01a	396.60 ± 34a	23.74 ± 4.60a

Note: Means (+ S.E.) of treatments within the same column and depth with the same letter are not significantly different from one another at α = 0.05.

TABLE 6. STATUS OF K AND Ca AT VARIOUS SOIL DEPTHS WITH AND WITHOUT EMPTY FRUIT BUNCHES (EFB) THREE MONTHS FROM COMMENCEMENT OF TRIAL

Soil depth (cm)	Treatment	Total K	Exch. K	Total Ca	Exch. Ca
		------------------------------(cmol(+) kg^{-1} soil)-------------------------			
0-15	+EFB	4.52 ± 1.92a	4.06 ± 1.81a	3.63 ± 0.78a	1.32 ± 0.31a
	-EFB	0.95 ± 0.18a	0.89 ± 0.18a	1.97 ± 0.18a	0.98 ± 0.09a
15-30	+EFB	1.96 ± 0.32a	1.63 ± 0.24a	1.74 ± 0.31a	0.76 ± 0.17a
	-EFB	0.70 ± 0.12b	0.62 ± 0.10b	0.92 ± 0.06b	0.49 ± 0.11a
30-45	+EFB	1.57 ± 0.30a	1.46 ± 0.27a	1.18 ± 0.16a	0.60 ± 0.12a
	-EFB	0.75 ± 0.05b	0.68 ± 0.05b	0.85 ± 0.09b	0.31 ± 0.05a

Note: Means (+ S.E.) of treatments within the same column and depth with the same letter are not significantly different from one another at $\alpha = 0.05$.

TABLE 7. STATUS OF Mg AT VARIOUS SOIL DEPTHS WITH AND WITHOUT EMPTY FRUIT BUNCHES (EFB) THREE MONTHS FROM COMMENCEMENT OF TRIAL

Soil depth (cm)	Treatment	Total Mg	Exch. Mg
		---------(meq kg^{-1} soil)---------	
0-15	+EFB	1.21 ± 0.18a	0.58 ± 0.15a
	-EFB	0.94 ± 0.07a	0.29 ± 0.05a
15-30	+EFB	0.86 ± 0.10a	0.35 ± 0.08a
	-EFB	0.64 ± 0.06a	0.17 ± 0.04a
30-45	+EFB	0.79 ± 0.06a	0.27 ± 0.06a
	-EFB	0.67 ± 0.03a	0.13 ± 0.02a

Note: Means (+ S.E.) of treatments within the same depth in column with the same letter are not significantly different from one another at $\alpha = 0.05$.

conditions which in this case were due to higher K and Ca levels. This would be in accordance with the observation made by Lopéz-Bucio *et al.* (2002), who reported that plants put out more roots in response to nutrients with the nutrients acting as a stimulus.

Sharing the view of Abel *et al.* (2002), the authors felt however that the increased root mass has important implications in that it improved the opportunity for palms to acquire other nutrients. Abel *et al.* (2002) were of the view that plants increased their chances of acquiring nutrients by putting out more roots to forage a larger volume of soil. The role played by EFB in stimulating the palms to produce more roots is therefore an important one.

In this experiment, only 100 kg of EFB were applied. In practice, however, tonnes of EFB are applied between palm rows. If the present result is to be applied to such a situation, it implies that there would have been a tremendous proliferation of roots resulting in the acquisition of large amount of nutrients. Results from this experiment suggest that total root mass increased under the applied EFB. There was no indication of any particular root order increasing significantly under the EFB. The increase in total root mass would explain why palms treated with large quantities of EFB have better nutrient status and higher yields. The important point here to consider is that increasing the root mass would be the way forward if the palms are to produce more fruit.

Increasing root mass however would not be the only reason why palms increase their yields. Improvement in soil nutrient status, moisture and a host of other factors would be important as well as this study shows.

Changes in some chemical properties of the soil after applying EFB were anticipated because there are already studies (Wingkis, 1998; Lim and Zaharah, 2000; 2002) on the subject. Changes in the soil chemical properties, in this case at the 0-15 cm soil depth, include a significant increase in soil pH, *i.e.* from pH 4.14 to pH 4.80, and significant increases in soil available P and moisture. All the three changes appeared to impact each other. When soil pH increased, it led to an increase in available P. This increase in available P is an important development because palms require it for many of their metabolic processes that require energy (Raghothama and Karthikeyan, 2005). The increase in available P at the 0-15 cm soil horizon implied a better opportunity for roots that were already present at that horizon to acquire P. The better soil moisture condition further enhanced this absorption opportunity. There was no doubt that applying EFB improved the soil conditions.

The tertiary roots, which have quaternary roots growing out from them, are mostly found in the 0-15 cm soil horizon. These roots arise from the secondary roots, which in turn arise from the primary roots. As such, for an increase in the mass of tertiary and quaternary roots to happen, there must first be an increase in root mass in the 30-45 cm soil horizon where most of the primary and secondary roots are to be found. The secondary and tertiary roots would then be able to grow towards the surface of the soil to take advantage of the higher amount of P that is found there. Several authors (Russel, 1977; Rajkai Végh, 1991; Nielsen *et al.*, 2001, Yano and Kume, 2005) have already observed in various plant species that plants put out more roots in a resource-rich soil patch. For example, barley plants produced more roots when there was a higher concentration of P in the soil (Rajkai Végh, 1991). When phosphate or nitrate was placed in a certain manner near a pea plant (*Pisum arvense*), more roots were formed near that nutrient source (Russel, 1977). Similar observations were made in *Zea mays* L. (Yano and Kume, 2005) and in common bean (*Phaseolus vulgaris* L.) (Nielsen *et al.*, 2001).

Potassium in EFB, which leaches out into the soil, would have contributed to the higher level of K in the soil seen in this experiment. Hence, when large amounts of EFB are applied, *e.g.* 37.5 t ha^{-1}, the K that is leached into the soil will be taken up by the palm, causing the leaf K level to increase as observed by Lim and Zaharah (2002). The high K level in the palm fronds is important as K is needed for the export of photosynthate from the shoots to the roots and enables the subsequent development of roots (Hermans *et al.*, 2006). The larger mass of roots from EFB application therefore could have been due to the large amount of K available in the soil.

In turn, the high amount of K in the soil may possibly have led to increase Ca levels at the various soil depths. This is to be expected as K would displace the Ca from the clay exchange sites. This higher Ca level will be beneficial to the palms if the palms are faced with potential Ca deficiency. The present study, however, could not distinguish the source of Ca as coming from the soil or from EFB.

Data derived from these observations show the unchanged status of soil total N, C and CEC three months after applying EFB. This is because, compared to K, N within EFB takes a longer time to be released (Lim and Zaharah, 2000). The amount of C in the soil from decaying roots also would not have increased significantly in comparison to the control. However, it was more likely after six months for soil C to increase, with most of the carbon coming from decaying roots. As such, the CEC of the soil would not increase until possibly after six months. All this implied that continuous application of EFB would be required.

An interesting observation from this experiment is the rapid increase in oil palm roots three months after EFB was applied to the soil. Equally fascinating was the rapid decline in the root mass three months later. This appears to suggest that roots that were stimulated to grow into the resource-rich patch lived for only three months and then died off. In zero-EFB soil, such root turnover was not observed to occur. Could it be that the palms shed off excess roots when the resource-rich patch was no longer there? If this was so, then continuous application of EFB, at least once in every three months, would ensure the continuous presence of roots in that patch where EFB were applied. This study, however, suffered from a lack of soil nutrient data six months after EFB application. The additional data would have thrown some light on why there was no change in root mass after six months.

The oil palm root is known to live for a certain period of time after which it dies and decomposes. However, what exactly is the life span of the oil palm root is still difficult to quantify. Henson and Chai (1997) found that it was rather complicated to determine the life span of a root. Lamade *et al.* (1996), however, suggested a figure of about 20% annual turnover. Mohd Haniff *et al.* (2003) gave a figure of about 20% root turnover over a period of three months. They suggested that the annual turnover may be higher but cautioned that further observations were necessary. The data presented here suggest that by applying EFB, many roots can be stimulated to grow into the EFB-treated area within three months. After another three months, much (about 60%) of these roots will die off. It is therefore easy to see why there is much difficulty in trying to quantify this aspect of the oil palm roots. Root turnover appears to be influenced by the substrate applied onto the soil; in other words, root turnover for areas with an organic substrate is different from that without an organic substrate.

There are many benefits in quantifying the turnover rate of the oil palm roots. For example, it is important that fertilizer application is made at a time when the amount of oil palm roots is on the increase or at its optimum. Under such a situation, there will be a good chance that most of the fertilizers that are applied would be taken up by the roots, assuming that the environment (*i.e.* sufficient rainfall, good soil structure) is conducive for nutrient uptake. If, however, fertilizers are applied when the amount of roots is at its minimum, then it is reasonable to assume that a less amount of nutrients will be taken up by the roots.

It is difficult to determine if loss of roots has any impact on the normal functioning of a palm. The oil palm produces a large amount of roots, and it is currently assumed that the loss of some roots would not pose any problem to the normal functioning of the palm. Tinker (2000), however, felt that the annual root turnover is large and may affect the growth of a palm. Mohd Haniff *et al.* (2003) expressed the same sentiment. However, if a palm is growing under marginal growing conditions, *e.g.* poor soil structures and/or dry conditions, the loss of some roots may affect its normal functions and hence, growth. Under a challenging environment, the rate of turnover may be more compared to palms growing under normal optimal conditions. Hence, knowing the reasons and conditions for this turnover is crucial if any effort to provide suitable conditions for optimum palm growth is to have any chance of success. Providing optimal conditions for the roots ensures that they live longer and function efficiently for a longer period of time.

The root mass of oil palm, in general, is found to be highest at the 15-60 cm depth (Chan, 1976). This soil horizon appears to be the 'active area' where most of the root mass is found. As such, it is not surprising that the response of the roots following EFB treatment first occurred here. Chan (1976) also observed that much of the root mass comprised of primary roots followed by secondary and then tertiary roots. This present study seems to point to the idea that for any treatment to be effective in causing roots to proliferate, the treatment must first influence the primary roots. The secondary and tertiary roots would then proliferate from the primary roots.

CONCLUSION

Application of EFB significantly increased the opportunity for palms to acquire nutrients after three months. The improved opportunity arose from an increase in available P at the 0-15 cm depth, where most of the tertiary and quaternary roots are present. Improved opportunity also arose from a significant increase in root mass at the 30-45 cm soil depth. There were also increased amounts of available K and total Ca at this depth. As such, the significant increase in root mass together with significant increases in available K and Ca improved the opportunity for the palm to acquire these two types of nutrients. There were other opportunities as well because an increased root mass implied that there was better opportunity for the palms to acquire other nutrients too.

The higher root mass in the EFB plots compared to the zero-EFB plots was not sustained after six months. The better soil chemical properties in the EFB-treated soil patch did not seem to be able to sustain a larger root mass compared to a palm not treated with EFB. The impact from this brief proliferation of roots in relation to EFB application on production and leaf nutrient status however may be able to last for up to two years. The results from an experiment carried out by Lim and Zaharah (2000) suggest this. In their experiment, they found that one application of EFB at 37.5 t ha^{-1} yr^{-1} resulted in an increased bunch yield two years later. Whether this increased yield was due to one period of time when acquisition of an abundant amount of nutrients was able to occur because of the large amount of EFB applied is something that is worthwhile pursuing. At the moment, it would appear that these enhanced opportunities for the palms to acquire nutrients may have a significant impact on FFB production two years later. It would be prudent therefore to conduct experiments to test this hypothesis.

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