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EFFECTS OF SEVERING OIL PALM ROOTS ON LEAF NUTRIENT LEVELS AND P UPTAKE

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ABSTRACT

Physical damage to oil palm roots affects the palm's ability to acquire nutrients. In spite of this huge impact on the palm, the effects of root loss on palm nutrient status are unknown and this is unfortunate because optimal palm nutrient status is an important factor in fruit production.

In trying to understand the effects of damage to the roots and the consequent effects on the palms, the impact of root damage was simulated by severing roots within 0%, 25% and 50% of the palm circle. Five months after the roots were severed, changes in leaf nutrient levels in the various treatments were observed. Each treatment was replicated five times, using one palm per replicate.

The impact of losing 25% of the roots within the palm circle changed the leaf K concentration and also the N:K ratio significantly ($p < 0.05$) compared with a loss of 50% of the roots within the palm circle. However, palms which lost 25% and 50% of the roots within the palm circle did not show any significant change ($p > 0.05$) in the N, P, Mg and B leaf concentrations compared to control.

Further assessment of the impact of root loss on nutrient uptake by the palm, especially by the surviving tertiary roots, was made using ^{32}P isotope. Five surviving tertiary roots from each treatment were placed in contact with the ^{32}P solution, and the amount of isotope absorbed by the palms from the various treatments over a fixed time was measured. No difference in the amount of the isotope absorbed was observed.

Keywords: oil palm roots, nutrient uptake, root damage, ^{32}P isotope.

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INTRODUCTION

It is believed that the larger root mass of palms planted in the more fertile inceptisols compared to the oxisols (Goh *et al.*, 2004) may have been an important factor for the higher fresh fruit bunch (FFB) production in the former because the palms would have better chance of intercepting water and nutrients. It seems reasonable, therefore, to think that for palms planted on oxisols, the proliferation, preservation and effective functioning of their roots would be important if they are to have an equally high FFB production as those palms planted on the more fertile soil.

The impact of a severe drought on FFB production in Southeast Asia in 1997 led to many studies on the subject over the ensuing two years. Caliman and Southworth (1998) and Foong (1999) reported on various aspects of the subject. Trying to protect the roots under drought conditions is difficult especially when the only source of water, *i.e.* a river, dries up as well. As the soil gradually dries up, more roots would correspondingly die off too due to a lack of water and nutrients. The obvious implication of such a situation is a decline in the water and nutrient status of the palm, which will subsequently affect yield.

Sometimes roots are infected and killed by diseases such as *Ganoderma* basal stem rot, water-logging, or mechanical injury inflicted by equipment normally used in agricultural activities. Undoubtedly, the palms will eventually recover from the injuries unless the damage is too extensive and serious. The question then remains: how much damage to the roots could a palm sustain before

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nutrient changes start to take place within the palm that would ultimately affect its FFB production?

It is believed that the palm may have a mechanism that enables it to recover from and survive injuries inflicted on its roots. Tinker and Leigh (1984) proposed that oil palm roots may have the capability of adjusting its rate of nutrient uptake in response to such injuries. For example, when a plant loses part of its root mass due to disease or mechanical injuries, the nutrient status of the palm is affected. Over time the palm would have experienced a nutrient deficient condition. To overcome this deficient condition, the remaining surviving roots increase their rate of nutrient uptake to compensate for the loss. This suggestion could have been based on the Michaelis-Menten principle of nutrient uptake.

In this principle, the rate of nutrient uptake, *V*, is affected by the maximum uptake rate (V_{max}) of the plant. For example, when a plant is experiencing a nutrient deficient condition because it has lost some of its roots and is unable to acquire its requirement of nutrients, V_{max} for the remaining surviving roots increases. It follows from the formula that when V_{max} increases, V would increase as well. As such, the plant improves its chances of acquiring the much needed nutrients in its effort to overcome the deficient condition. The proposal put forward by Tinker and Leigh (1984) was not new because some aspect of it had been studied in the past. A study on a cereal plant by Edwards and Barber (1976), later cited by Barber (1984), showed that the rate of nutrient uptake by roots increased when part of the total root mass was removed. This observation, however, was made on roots grown in liquid culture. It is not clear at this point in time if such a change would happen as well for roots growing in soil because there would be many other factors in the soil that could prevent the observation of such adaptation. However, assuming that such adaptability does exist within the oil palm, it would then be logical to expect the palm's nutrient status to remain unchanged even if some portions of the roots were severed from the palm.

Hence, the objectives of this experiment were to: (i) investigate the changes in leaf nutrient status, and (ii) to determine any change in the rate of nutrient uptake by the surviving tertiary roots of the oil palm after various proportions of roots had been severed from the palm.

MATERIALS AND METHODS

Investigating Changes in Leaf Nutrient Status after Root Removal

Palms of about three years of age which had been planted on Rengam series soil were used. The physical and chemical properties of the soil are shown in *Table 1*. One layer of empty fruit bunches (EFB) was placed in a ring around the weeded circle of each palm, and left for six months. After this period of time, the soil around the palm was dug to severe the roots from the palm. The entire circle around the palm was considered to be 100% (*Figure 1*). Three treatments were imposed, each representing 0%, 25% and 50% of the palm circle.

TABLE 1. PHYSICAL AND CHEMICAL PROPERTIES OF RENGAM SERIES SOIL IN WHICH PALMS USED IN STUDY WERE PLANTED

Depth (cm)	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	pH	Organic C (%)	Base saturation	C.E.C
0-15	35.6	21.0	5.1	38.3	3.9	1.62	20.71	7.00
15-30	34.9	21.0	3.7	40.4	3.6	1.26	27.30	6.52
30-45	32.2	18.8	5.4	43.6	3.6	0.85	25.00	4.56

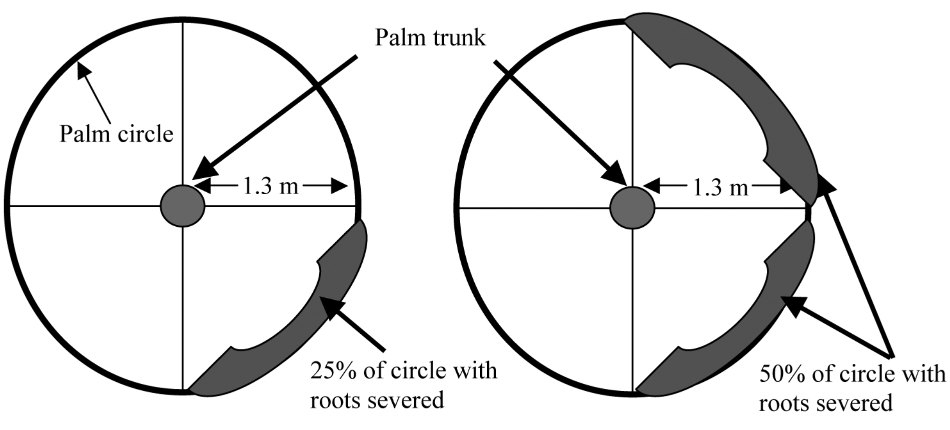

Figure 1. The palm circle was divided into four equal quadrants so that roots in 25% and 50% of the circle could be severed.

To severe the roots according to the treatments, the palm circle was divided equally into four quadrants (*Figure 1*). A backhoe was then used to dig the soil at about 1.3 m away from the palm base to a depth of 1.5 m. In doing this, much of the roots were severed from the palm. For the treatment in which roots from 25% of the palm circle were severed, the backhoe dug the soil within one quadrant. To severe roots within 50% of palm circle, roots from two quadrants were severed. After digging, the mixture of soil and cut-off roots was then placed back into the hole.

Each treatment was applied to one palm, and replicated five times. The treatments followed a randomised complete block design (RCBD).

Leaflets from frond 17 were collected from the palms five months after severing the roots, and the leaf tissues were analysed for N, P, K, Mg and B. Data obtained were analysed by analysis of variance (ANOVA) using the SAS statistical package (SAS, 2001).

Investigating Changes in Nutrient Uptake by Tertiary Roots

Seven days after the treatments were implemented, tertiary roots were selected at random and treated with ^{32}P. Tertiary roots were used for this investigation as they could be easily found isolated on the surface of the soil. A piece of cotton wool soaked with 10 ml solution of KH_2PO_4 containing 5 μg P ml^{-1} and 4 μCi of carrier-free ^{32}P was placed in a 25-ml glass vial. The tertiary root which was creamy white in colour was randomly selected from among the remaining living roots, and was inserted into the glass vial, placing it in contact with the cotton wool (*Figure 2*). The root, still attached to the palm, was left in the vial for 48 hr to allow it to absorb the ^{32}P. Five tertiary roots from each palm were selected at random and treated with the ^{32}P isotope, giving a total of 25 tertiary roots treated with the ^{32}P isotope for each treatment. After 48 hr the roots were cut from the palm, placed in clean glass vials and oven-dried at 70°C for 72 hr until constant weight was achieved.

Figure 2. A tertiary root placed in contact with cotton wool soaked with KH_2PO_4 solution.

The dry weight of the roots was then recorded. Each root was cut into lengths of approximately 0.5 cm long, and placed in a clean counting cup. A 10 ml solution of scintillation cocktail (Ultima Gold) was then pipetted into the cup and placed in a liquid scintillation counter (model Tri-Carb 3100TR by Packard-Packard BioScience Co.) for 0.1 min exposure time. Count per minute (cpm) was recorded. The data were transformed using $\log_{10}$ and then subjected to ANOVA.

RESULTS

Severing 25% of the roots resulted in a significant increase ($p < 0.05$) in the leaf K concentration (*Table 2*). As a result of this change in K concentration, the N:K ratio also changed significantly ($p < 0.05$). The K concentration was high enough to cause a difference in the N:K ratio even though N concentration did not change.

The above effects were not observed in palms that had 50% of the roots severed. However, for the other nutrients (N, P, Mg and B), both treatments were not significantly different from the control (0%). Thus, a loss of roots even up to 50% did not lead to any observable change in leaf nutrient status (*Table 2*).

In the ^{32}P study, the amount of ^{32}P taken up in the tertiary roots was examined. Uptake of ^{32}P was similar across all treatments (*Table 3*). Due

TABLE 2. MEANS (± S.E.) OF VARIOUS LEAF NUTRIENT CONCENTRATIONS (percentage of dry matter) FROM PALMS WITH VARIOUS PROPORTIONS OF ROOTS REMOVED

Roots severed (%)	N	P	K	Mg	B	N:K
	-------------------	-------------------	-------%-------	-------------------	-------------------	mg kg^{-1}
0	2.79 ±0.03a	0.166 ±0.01a	1.11 ±0.06ab	0.21 ±0.03a	11.66 ±0.63a	2.55 ±0.14b
25	2.68 ±0.05a	0.162 ±0.001a	1.27 ±0.03a	0.23 ±0.01a	11.92 ±0.82a	2.11 ±0.07a
50	2.82 ±0.04a	0.170 ±0.001a	1.07 ±0.04b	0.24 ±0.01a	11.26 ±0.26a	2.64 ±0.09b

Note: Means within a column followed by the same letter are not significantly different from another at p<0.05.

TABLE 3. MEAN RADIOACTIVE COUNTS PER MINUTE (cpm) FROM THE THREE TREATMENTS

Roots severed (%)	Mean cpm g^{-1} root (± S.E.)
0	$1.6 \times 10^5 \pm 2.9 \times 10^4$a
25	$1.2 \times 10^5 \pm 2.2 \times 10^4$a
50	$1.6 \times 10^5 \pm 3.7 \times 10^4$a

Note: Means within a column followed by the same letter are not significantly different from one another at $p<0.05$.

TABLE 4. COEFFICIENTS OF VARIATION (CV) BEFORE AND AFTER log_{10} TRANSFORMATION

Roots severed (%)	0	25	50
CV (%) before transformation	63.6	66.4	79.5
CV (%) after log_{10} transformation	8.3	4.8	6.8

to the high variability among the data, $log_{10}x$ transformation was applied before ANOVA was carried out. Coefficients of variation of 4.8%-8.3% were obtained after transformation (*Table 4*).

DISCUSSION

Observations on leaf nutrient concentrations five months after the roots were severed showed that all the treated palms were in no immediate danger of suffering from any nutrient deficiency. All elements were at an optimal level. Thus, severing roots from palms planted in the Rengam series soil may not immediately induce drastic changes in palm nutrient status, but one would reasonably expect the palm to react to the damage by taking steps to repair and rebuild its root mass. Indeed, the experiment also showed that the palms did react to the damage as a significantly lower N:K ratio and a significantly higher K concentration were observed. Compared with the control, the N:K ratio of the 25% and 50% treatments was about 17% lower and 3% higher, respectively, while the K concentration was about 14% higher and 3% lower, respectively.

The significantly lower N:K ratio for the 25% treatment compared with the other two treatments was the result of a higher K concentration. This change involving N and K does not come as a surprise as the element K plays an important role in loading sugars into the phloem vessels (Hermans *et al.*, 2006). The significantly higher ($p < 0.05$) K concentration shows that the palm's physiological system was preparing to transport sugars to the roots. Nitrogen is an essential component of proteins, nucleic acids and various coenzymes, and plays an important part in plant physiological processes. The element N is also important for chlorophyll synthesis and, thus, is critical for photosynthesis. The process of photosynthesis results in the production of carbohydrates, some of which are used for the repair and regeneration of roots. It seems reasonable then to suggest that when a palm sustains injuries to its root structures, the amount of N in its reserves needs to be maintained as it is crucial for sugars to be formed. Together with an elevated K concentration, this sugar is sent below the soil and converted to energy for the necessary repairs and regeneration of the roots to take place.

It was observed that the N:K ratio for the 50% treatment did not differ from the control. This may have something to do with the palm's ability to sustain damage. Possibly, severing the roots from 50% of the palm circle may have been too drastic for the palm to respond accordingly.

The above description of N and K interaction has several implications on the way foliar analyses results are interpreted to determine fertiliser recommendations. The significant changes in K and N:K ratio for the treatment with roots severed from 25% of the palm circle suggest that the roots had been damaged and that the palm's physiological system was able to respond to counter the damage. Agronomists analysing and interpreting oil palm foliar analyses results are possibly not even aware of such a development happening underground. There is, therefore, a need to be able to detect this significant shift in N:K ratio so as to understand the extent of damage sustained by the roots.

The results obtained suggest that if a palm lost roots from 50% of the palm circle, the palm also lost some degree of its ability to respond to the damage. The implication of this inability is that less amounts of nutrients would be acquired because only roots from the other half of the circle remained. The palm, however, would continue to use the nutrient reserves stored in its trunk and fronds for its normal functioning. Thus, unless the amount of nutrients utilised is replenished the palm's nutrient status will degenerate over time. As seen from the above, it is reasonable to assume that much of the N reserves will be utilised for carbohydrate synthesis to be used for the repair and regeneration of roots. If this reserve is not replaced on time, then it is reasonable to assume that FFB production would be affected. When roots within half the circle were damaged it is likely that repairs and regeneration of the roots would take a longer time compared with palms which sustained a 25% loss of roots from the circle.

The results obtained from the present study do not support the suggestion by Tinker and Leigh (1984) that the rate of nutrient uptake of surviving roots increases when the palm loses some portion of its roots. At even the extreme treatment where roots from 50% of the circle were severed, nutrient uptake by the remaining living tertiary roots, which was reflected by the total P absorbed over a fixed time, was not significantly different from the control. There could be many possible reasons for this situation but one reason stands out; it may very well be related to the nutrient status of the palm. In this experiment, the palms used were planted in Rengam series soil, a soil classified as suitable for oil palm planting. In addition, the palms had a history of being well fertilised under commercial planting management. Hence, it is unlikely that the nutrient status of the palms used here would be negatively affected even after some roots were removed. Hence, the tertiary roots used here would have come from palms that had an optimal nutrient status even though the test was carried out one month after their roots were removed. Unfortunately time and resources were constraints in this study as it is suspected that the observed changes will continue to occur over time.

It has been mentioned by Classen and Barber (1977) that the influx of K into roots varies with the nutrient status of a plant. They found that K influx into the roots of plants grown in poor nutrient conditions was higher than into roots of plants well supplied with K. Jungk and Barber (1974) came to the same conclusion when they experimented with phosphorus. Observations by both Jungk and Barber (1974) and Classen and Barber (1977) thus support the idea that palms already having an optimal nutrient status do not adjust their rate of absorbing a nutrient.

It is suspected then that given enough time some differences in nutrient uptake among the tertiary roots of the three treatments in this experiment might have become apparent, provided of course that the amount of roots removed was critical enough and the rate of root rejuvenation was too slow to support the optimal nutrient status of the palm. If such a situation was achieved, *i.e.* sufficient roots were removed such that the nutrient status of the palms was negatively affected, then according to Jungk and Barber (1974) and Classen and Barber (1977) nutrient uptake by the surviving roots would increase, triggered by the deteriorating nutrient status of the palm. It would seem that with the large amount of roots that an oil palm is capable of producing, losing roots even up to 50% of the palm circle may not have any major impact on the palm nutrient status, especially if the palm is planted on fertile soil, such as the Rengam series, and has a good history of fertiliser management.

CONCLUSION

When a palm loses some portion of its roots, nutrient changes occur. The frond K level increased significantly for palms that lost 25% of the roots within the palm circle, compared with palms which lost 50% of the roots within the palm circle. Consequently, the N:K ratio for palms that lost 25% of the roots within the palm circle was significantly lower than in the other two treatments. The amount of P absorbed by the tertiary roots over a fixed time for all the treatments was the same, indicating that nutrient uptake was not affected at the early stage of root loss, possibly when the nutrient status of the treated palms was still at an optimum.

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