SEASONAL FLUCTUATIONS IN OIL PALM LEAF NUTRIENT LEVELS

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INTRODUCTION

In West Malaysia, oil palms are generally sampled only once a year for diagnosis of nutrient status. If fluctuations in leaf nutrient levels during the year are large, then for a valid interpretation of a single sampling, leaf collection must be narrowly restricted to specific times of the year so that the factors which cause the fluctuations are always at a similar level, or the results must be adjusted according to the levels of the factors causing the fluctuations.

In Africa, where the climate is highly seasonal, marked leaf nutrient fluctuations in oil palm have been reported. SMILDE and CHAPAS (1963) and SMILDE and LEYRITZ (1965) found that in Nigeria, leaf N and P concentrations consistently decreased during the dry season and increased again during the rains. A similar effect has also been observed by BROESHART (1956), HASSELO (1961) and OCHS and OLIVIN (1976) in other West African countries, but SCHEIDECKER and PREVOT (1954) and BROESHART (1957) in a later experiment obtained contrary results. SMILDE and CHAPAS (1963) did not observe any consistent changes in the concentration of leaf bases, but BROESHART (1956, 1957) observed higher levels of leaf potassium and calcium in the dry season. On the other hand, OCHS and OLIVIN (1976) have reported that leaf K is lowest during the dry season in Dahomey.

In the oil palm growing areas of West Malaysia seasons are less marked, but a similar pattern of change in leaf N has been recorded by MARTINEAU ET AL. (1969), who found a level of 2.53% N at the end of a dry period, which increased to 2.74% when the rains returned. BOLLE-JONES and RATNASINGAM (1954) also found that for rubber trees in West Malaysia, the nitrogen concentration in leaves was significantly and positively related to the rainfall in the month preceding sampling. For leaf nutrient levels in oil palms in West Malaysia, NG and THAMBOO (1966) and Socfin Agricultural Department (1973) have reported considerable monthly fluctuations in all major nutrients, and RAJARATNAM (1972) has reported very appreciable weekly changes in boron. Thus leaf nutrient fluctuations appear to be important in Malaysia as well as in Africa, and the investigation reported in this paper was undertaken with the purpose of identifying the factors which cause fluctuations in Malaysia, so that in future they can be taken into account when interpreting results from a single sampling.
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MATERIALS AND METHODS

Fluctuations in leaf 17 nutrient levels in oil palms, from 19 fertilizer trials in West Malaysia run by different organizations, were examined over stable yield periods of 4–5 years. The identity of these trials and a brief description of soil types is given in Table 1. The selected periods of investigation, and number of sampling dates and average leaf 17 nutrient levels over these periods are shown for each trial in Table 2. Full details of these trials including site properties and yield and leaf nutrient responses to the fertilizer treatments have been described by Foster (1967), Foster and Goh (1976) and Foster and Chang (1976b). The palms in the trials were sampled at least once, and sometimes as often as 4 times a year. In one year of trial 1, leaf samples were collected every month. The mean trial values
of leaf per cent N, P, K, Mg and Ca were determined for each sampling date, and it is the variation in these mean values at each site which was examined in relation to seasonal influences.

Factors investigated in relation to leaf nutrient fluctuations included rainfall, soil available water and yield level in the months immediately preceding leaf sampling, and also the time from the last fertilizer application. For nutrients mobile in plants (which include N, P and K) leaf levels are probably determined mainly in the months immediately before sampling, so that for these nutrients this is the most important period to consider. Percentage available water in the top 90 cm of soil was estimated for each day of the selected period of each trial from soil water holding capacity measurements and daily rainfall and evapo-transpiration data. In these calculations, run-off was ignored and no account was taken of any water table. Evapo-transpiration from the soil/palm system was assumed to be equivalent to evaporation.
from an open water surface over the whole range of percentage available water. Average available soil water in each month was then calculated from the daily estimates. It was considered that monthly F.F.B. yield data would be meaningless as the number of harvesting rounds per months was not fixed. Instead, 3-month moving yield averages were calculated (the yield estimate for June for example being calculated from the average yield obtained over May, June and July).

RESULTS

Average seasonal variation in leaf nutrient levels

Leaf nutrient levels at different dates in a particular trial were expressed as a percentage of the average levels obtained in that trial. The variation in such data obtained from all trials on coastal and inland soils (grouped separately) was determined, and the coefficients of variation are shown in Table 3. Since all the results are trial means (derived from 81 plots), error due to sampling will be negligible, and the variation observed is therefore almost entirely due to seasonal factors. The coefficients of variation for leaf bases (generally between 6 and 8 per cent) are seen to be higher than the coefficients of variation for leaf N and P (generally between 3 and 4 per cent).

| Table 3. SEASONAL FLUCTUATIONS IN MEAN TRIAL LEAF 17 NUTRIENT LEVELS – COEFFICIENTS OF VARIATION |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| No. of sampling dates | Leaf Nutrient |
| Coastal trials | 60 | 4.02 | 3.35 | 5.90 | 5.98 | 10.69 |
| Inland trials | 88 | 3.78 | 3.66 | 7.87 | 7.57 | 6.21 |

Average seasonal variation in rainfall, available water and yield

The average monthly seasonal variation in rainfall, soil moisture and yield level estimated in two contrasting inland situations and a typical coastal situation in West Malaysia are shown in Figs. 1 to 3. In the first figure, are shown results for trial 27 on a typical sandy clay inland soil (Harimau) derived from granite. At this site average available soil water declines below 40 per cent (approximately equivalent to a soil water tension of pF3) in only 2 months of the year, and yield shows little fluctuation throughout the year. In contrast, as shown in Fig. 2, average available soil water is estimated to be below 40 per cent in 10 months of the year in trial 41, which is on a sandy clay loam inland soil (Durian/Batu Anam) derived from shale. As would be expected, yield level varies considerably throughout the year in this particular trial. Finally, in Fig. 3 are presented results for trial 5 on a typical coastal clay soil (Selangor) derived from marine alluvium, in which average available soil water is apparently below 40 per cent in 7 months of the year. In fact, due to the presence of a water table in the wet season the sub-soil probably dries out more slowly than calculated, but any water table will have little effect on the available water in the topsoil where the majority of feeding roots are situated. The marked yield fluctuations observed in this trial are in accord with the considerable variation in soil available water estimated to occur.

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Figure 1. Mean monthly rainfall, available soil water and F.F.B. yield estimated for trial 27 (broken lines indicate standard deviations).
Figure 2. Mean monthly rainfall, available soil water and F.F.B. yield estimated for trial 41 (broken lines indicate standard deviations)
Figure 3. Mean monthly rainfall, available soil water and F.F.B. yield estimated for trial 5 (broken lines indicate standard deviations).
Leaf nutrient fluctuations within individual trials in relation to rainfall and available water

Percentage leaf nutrient fluctuations in individual trials were correlated with rainfall and average available water in periods of 1, 2 and 3 months preceding leaf sampling.

In the coastal trials, almost all correlations between leaf N, P and K fluctuations and either rainfall or available water were found to be positive. Because of the few degrees of freedom (often only 3) the correlations with leaf N and K reached a significant level in only a few cases. However the correlations between leaf P and average available soil water in the 3 month periods preceding sampling were significant in as many as 5 out of the 9 coastal trials on mineral soils (No's 1, 3, 4, 6 and 7). Correlations between leaf P and soil water in shorter periods preceding sampling were not as good, and not a single correlation between leaf P and rainfall was significant. Leaf Mg and Ca fluctuations in coastal trials showed no consistent correlations with rainfall or soil moisture.

In the inland trials, correlations between leaf N and P fluctuations and rainfall or soil moisture were as frequently positive as negative. Thus leaf N in both trials 25 and 28 was significantly correlated with available soil water in the 3 month period preceding sampling, but in the former case the correlation was negative whilst in the latter case it was positive. Correlations between leaf K and available water preceding sampling were mostly negative on inland soils, and in trials 21, 22 and 27 the negative correlations were significant. As in the coastal trials, there were no consistent correlations with leaf Mg and Ca in inland trials.

Overall correlations with leaf nutrient fluctuations in coastal and inland areas

In order to obtain overall correlations with leaf nutrient fluctuations which would be widely applicable, data from different trials were combined for analysis. However coastal and inland trial data were kept separate as the correlations within individual trials showed that they behaved differently. Data from trials 10, 28 and 61 were omitted since either the sites were anomalous (e.g. acid sulphate) or the data was incomplete. This left results from 46 different sampling dates derived from 7 coastal trials, and from 74 different sampling dates derived from 9 inland trials. As before, the leaf nutrient data were percentages of the mean values obtained over the whole period of investigation in each trial. This form of expression allows results from different trials to be combined even though absolute values from the different trials are very different. Correlations were determined with average soil available water, rainfall and fresh fruit bunch yield level, over both one and three month periods preceding leaf sampling. Correlations were also calculated with the number of months since the last fertilizer application, and in order to detect any consistent time trends, with the number of months away from the middle of the total period of investigation in each trial. All simple correlation results for coastal and inland soils are shown in Table 4.

On coastal soils, fluctuations in leaf P and K nutrient levels were found to be highly positively correlated with estimated available soil moisture prior to leaf sampling. The most significant correlation was obtained with soil moisture estimated over a one month period immediately before sampling. No significant correlations were found between leaf nutrient fluctuations and rainfall or yield levels prior to leaf sampling. Leaf N and P variation on coastal soils was found to be significantly negatively correlated with the date of sampling, but leaf nutrient levels were not found to be significantly related to time of fertilizer application (the latter was rather expected as there was little variation on coastal soils in the period between fertilizer application and leaf sampling).
TABLE 4. SIMPLE CORRELATION COEFFICIENTS FOR THE LINEAR RELATIONSHIPS BETWEEN PERCENTAGE FLUCTUATIONS IN LEAF 17 NUTRIENT LEVELS AND AVERAGE RAINFALL (R), ESTIMATED AVAILABLE SOIL WATER (M) AND F.E.B. YIELD LEVEL (Y) OVER BOTH ONE AND THREE MONTH PERIODS BEFORE LEAF SAMPLING (INDICATED BY SUBSCRIPTS 1 AND 3 RESPECTIVELY), AND TIME FROM BOTH THE LAST FERTILIZER APPLICATION (T_F) AND FROM THE DATE OF THE MIDDLE OF THE PERIOD OF INVESTIGATION (T_P).

(*, **, *** = SIGNIFICANT AT 5, 1 AND 0.1% LEVEL RESPECTIVELY).

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<th>R_3</th>
<th>M_1</th>
<th>M_3</th>
<th>Y_1</th>
<th>Y_3</th>
<th>T_F</th>
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<tr>
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<td>.234</td>
<td>.257</td>
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The multiple correlation between leaf P fluctuations on coastal soils and soil moisture in the month before sampling plus date of sampling was found to be $R = 0.660^{***}$ (43 d.f.), appreciably better than the individual simple correlations. The partial correlations of leaf P fluctuations with soil moisture and sampling date were $r = 0.509^{***}$ and $r = -0.433^{**}$ respectively. Multiple correlations between leaf nutrient fluctuations and other pairs of independent variables were also determined, but none were significantly better than the individual simple correlations. The fitted regression equations for the most significant relationships found on coastal soils were:

- Percentage deviation of leaf N levels from mean = $-1.90T$
- Percentage deviation of leaf P levels from mean = $0.0482M - 1.04T - 2.38$
- Percentage deviation of leaf K levels from mean = $0.0892M - 4.57$

(where $T =$ time in years,
and $M =$ average percentage available moisture in the top 90cm of soil in the month before sampling).

These equations indicate that leaf N and P levels decline on coastal soils at an approximate rate of 2 and 1 per cent per year respectively, and that leaf P and K levels may be up to 5 and 9 per cent higher respectively after a wet period compared with after a dry period.

On inland soils, fluctuations in leaf K nutrient level were found to be very highly significantly negatively correlated with both rainfall and estimated available soil moisture prior to leaf sampling. The most significant correlation was obtained with rainfall received over the three month period prior to sampling, and fluctuations in leaf Ca were also significantly negatively correlated with this measurement. Fluctuations in leaf Mg were significantly negatively correlated with average yield in the three month period prior to sampling. No other significant correlations with leaf nutrient fluctuation in palms on inland soils were noted, apart from a small negative relationship between leaf P and date of sampling. Correlations were also determined within smaller groups of data from selected inland trials, but no new relationships were found. However when only the 5 trials giving the highest responses to potash fertilizer were considered, the correlation between fluctuations in leaf K and rainfall in the three months period before sampling was considerably improved, the simple correlation coefficient being $-0.688^{***}$ (27 d.f.).

The fitted regression equations for the most significant relationships found on inland soils were:

- Percentage deviations of leaf P levels from mean = $-0.69T$
- Percentage deviations of leaf K levels from mean = $8.45 - 0.1424R_3$
- Percentage deviations of leaf Mg levels from mean = $5.97 - 1.596Y_3$
- Percentage deviations of leaf Ca levels from mean = $4.37 - 0.0616R_3$

(where $T =$ time in years,
$R_3 =$ rainfall in cm received during the three month period before sampling
and $Y_3 =$ F.F.B. yield in t/ha during the three month period before sampling)

These equations indicate that leaf P levels decline on inland soils at an average rate of 0.7 per cent per year, that a difference of 10 cm rainfall in the three months preceding leaf sampling causes a difference of 1.4 and 0.6 per cent in the levels of leaf K and Ca respectively, and that a difference of 1 tonne F.F.B. per hectare in yield during the three months before leaf sampling causes a difference of 1.6 per cent in the level of leaf Mg.
DISCUSSION

The object of this study was to investigate fluctuations in leaf nutrient levels due to seasonal factors. Variation in leaf nutrient levels due to sampling error was largely eliminated by considering only mean values derived from 81 individual samples, and changes in leaf nutrient levels due to changes in soil fertility were minimised by choosing 4–5 year periods during which mean yields remained fairly constant. To take account of any leaf nutrient changes which did still occur with palm age, correlations with time were determined so that corrections could be made if necessary. Only in the case of leaf N and P on coastal soils and leaf P on inland soils was any significant change with time observed, the concentration of these leaf nutrients being found to decrease with palm age. A decline with age in the levels of leaf N and P corresponding to optimal yields, in the same coastal trials, was noted by the authors in an earlier study (Foster and Chang 1976a) and attributed to the need to maintain balance with declining levels of leaf Ca. A decline in the level of leaf N and K with age is often observed in oil palm plantations on inland soils (OLLAGNIER et al., 1970; SOCFIN, 1973), and is probably due to a decline in the soil supply of these nutrients. In the present trials on inland soils, in which soil fertility presumably did not drop as yields remained constant, no decline in the level of N and K with palm age was observed.

After correction for any changes with palm age, seasonal fluctuations in the levels of leaf P and K on coastal soils were found to be highly significantly related to soil moisture prior to leaf sampling, whilst the levels of leaf K and Ca on inland soils were found to be significantly related to rainfall (or soil moisture) prior to sampling. However on the coastal soils the correlations were positive whilst in contrast on the inland soils the correlations were negative. It was mentioned in the introduction that earlier published results for oil palm have also been contrary. These opposite results are not surprising since a survey of the literature reveals frequent contradictory findings on the effect of soil moisture levels on leaf nutrient levels. Reviewing this subject, Richards and Wadleigh (1952) concluded that the majority of experiments published showed that an increase in soil moisture stress generally causes an increase in leaf per cent N and a decrease in leaf per cent K, but variable effects on the levels of other major nutrients. However Clements (1964) for sugar cane in Hawaii, and Archibald (1964) for soft fruit trees in Canada, have reported that leaf per cent N decreases with moisture stress, whilst Moss (1964) has shown that under equilibrium conditions leaf per cent K increases when the soil moisture level is reduced.

In West Africa the fluctuations in leaf N and P levels of oil palm can be largely explained by changes in the rate of mineralization of soil organic matter. During the dry season the soil microbial population becomes inactive and considerably reduced, so that little mineralization occurs. When the rains return the soil microbial population develops rapidly and very actively attacks the soil organic matter, part of which due to physical changes during the dry season is very readily mineralized resulting in a marked flush of available nutrients (Birch, 1959). In West Malaysia seasons are far less extreme, and the fact that leaf N is not generally significantly related to rainfall or soil moisture, indicates that changes in the rate of mineralization of soil organic matter is not a very important factor in this country.

On coastal soils in West Malaysia, fluctuations in the oil palm leaf levels of only P and K have been found to be significantly related to changes in soil moisture. In contrast to N and Ca, the concentration of these two particular nutrients in most soil solutions is quite inadequate to satisfy crop needs if they are only passively taken up in the transpiration stream. To meet crop requirements these nutrients have to move to the plant roots by diffusion, the rate of which is strongly influenced by the level of soil moisture. With increasing moisture stress, water films on
individual soil particles become thinner and continuity of these films from one particle to another may be broken (BROWN, 1953). In addition the solvent properties of water decrease as the films become thinner (RICHARDS and WADLEY, 1952). A number of workers (e.g. DANIELSON and RUSSELL, 1957; HIBBARD and NOUR, 1959; MEDERSKI and WILSON, 1960) have attributed poorer crop uptake of P and K at lower moisture levels to decreased ion diffusion in thinner moisture films in the soil, and it is suggested that it is this effect of moisture on nutrient diffusion rates in the soil which causes similar changes in leaf P and K levels in oil palm growing on coastal soils in Malaysia.

Due to different soil physical properties, average water stress is usually higher in coastal topsoils than in inland topsoils (FOSTER and GOH, 1976), so that a closer relationship between available soil moisture and palm uptake of P and K is to be expected on coastal soils. Thus the efficiency of P fertilizer recovery in oil palm fertilizer trials has been found to be significantly correlated with average available water in coastal, but not inland soils (FOSTER and GOH, 1976). In addition, although inadequate soil moisture may restrict uptake of nutrients from the surface horizon of coastal soils (where most of the applied P and K fertilizer is held), there is generally a plentiful supply of water in the lower horizons due to the presence of a water table. Thus on coastal soils, when uptake of P and K is limited by soil moisture, leaf dry matter is not likely to be concomitantly reduced by water stress, and leaf concentrations of P and K (on a dry matter basis) therefore drop significantly. In contrast, on inland soils, water stress is likely to limit nutrient uptake and depress leaf dry matter content at the same time, so that much smaller changes in the actual concentrations of leaf nutrients (on a dry matter basis) are to be expected.

For trial 1 on a coastal soil, leaf analysis results were available for 11 consecutive months, and this data is shown graphically in Fig. 4 together with corresponding available soil moisture and F.F.B. yield levels in the month preceding each leaf sampling. It can be seen that percentage levels of leaf N, P and K were lowest in the first 4–5 months of the period when the average level of available soil moisture was less than 20 per cent, and were highest in the last two months, when soil available moisture exceeded 75 per cent. The use of the correction equations derived for coastal soils is illustrated by the broken lines which represent leaf P and K levels corrected to 50% available water. After correction for the level of available soil moisture, fluctuations in leaf nutrient levels due to other factors are evident. These may be due to the effect of the fertilizer applied in February 1968 or to the very marked fluctuation in yield level, factors which are discussed later in this paper.

In contrast to the situation on coastal soils, the levels of K and Ca in leaf 17 of oil palms on inland soils are generally significantly higher during drier periods, and decline when rainfall increases. The drier the soil, the more concentrated becomes the soil solution, and MOSS (1964) found that under equilibrium conditions in a laboratory, this effect results in greater plant uptake of ions. However, conditions in the field are very different, and other explanations for the observed leaf nutrient fluctuations in oil palm on inland soils, seem more likely.

One possibility is that when the rains improve after a dry period, nutrients are transferred from older leaves (including 17) to meet a sudden high demand caused by an acceleration in the growth of younger leaves. This would seem particularly likely for K, which is very mobile within plants, and is also the nutrient in most limited supply on inland soils. The fact that the correlation between leaf K fluctuations and rainfall in inland areas is markedly increased when only the most K deficient trials are considered, supports this hypothesis. An increase in the dry matter content of leaf 17 itself, due to better moisture conditions, may also contribute to the decline in the concentration of K; and the smaller decline in Ca, which is very immobile within plants, may be entirely due to this effect.
Figure 4. Mean percentage levels of N, P and K in leaf 17 of oil palms in trial 1 in consecutive months, and corresponding average available soil moisture and F.F.B. yield levels in the month before each leaf sampling. (Broken lines indicate leaf P and K results corrected to 50 per cent available soil moisture)
On the other hand increased rainfall may depress nutrient uptake by leaching available soil nutrients out of reach of the palm roots or may directly wash nutrients out of the leaves. The fact that leaf N is not depressed by rainfall does not mean that serious soil leaching does not occur, for increased soil organic matter mineralization may balance any losses of this particular nutrient. The importance of leaching was revealed when fertilizer responses in the individual years of the inland trials were examined (FOSTER and GOH, 1976). The efficiency of crop recovery of both N and K fertilizers was found to be very significantly related to estimated water percolation beyond a 90 cm depth in the 3 months after fertilizer application. Direct losses from leaves can be very serious for K, but not generally for other nutrients. Thus NYE and GREENLAND (1960) have reported that K washed out of the leaves of high forest in West Africa amounts to approximately 200 kg/ha per year, but N losses are only about 12 kg/ha per year.

At present it cannot be concluded which of the effects discussed above are responsible for the fluctuations of leaf K and Ca in oil palms on inland soils which are negatively correlated with rainfall. More research is required to elucidate this matter. The factors which cause a decline in leaf K and Ca might also be expected to cause a decline in leaf Mg. However, due to the well-known antagonism between leaf K and Mg, the decline in leaf K would also tend to increase leaf Mg, so that no net change in leaf Mg may occur.

EMMERT (1959) has reviewed the effect of crop load on the leaf composition of fruit trees and found that leaf N, P, Ca and Mg generally increase with crop load, whilst leaf K tends to decrease. However for peach leaves, HAVIS and GILKESON (1951) found that leaf K only decreased if supplies were deficient. MCLUNG and LOT (1956) showed that in peach trees the increase in leaf nutrient concentrations with fruiting is due to a decrease in leaf dry matter, and the absolute levels of nutrients actually decrease.

COULTER (1958) studied the influence of fruiting cycle on the nutrient composition of oil palm fronds over a period of two years. No conclusion was possible for N, and leaf levels of P and Mg varied little over the sampling period. However, analogous to the results observed with soft fruit trees, Ca concentrations tended to be higher and K concentrations lower during periods of high bunch production. Similarly TAN (1974) noted that leaf K levels of oil palm on an inland soil in Malaysia tended to be lower when the majority of palms sampled were in a female phase. However in the present investigation no significant relationship was found between the fluctuations of any leaf nutrients and yield prior to sampling on coastal soils, and only a small significant negative correlation with leaf Mg was found on inland soils.

Finally we should consider the effect of time of fertilizer applications on leaf nutrient levels. WARRIAR and PIGGOTT (1973) have shown that levels of the major leaf nutrients rise rapidly within a few months of fertilizer application to deficient palms, and RAJARATNAM (1973) has observed that boron reaches a maximum only 6–8 weeks after soil application, and thereafter declines. In practice leaf sampling is never carried out until at least 3 months after the most recent fertilizer application by which time any increase in leaf nutrient levels has probably been achieved. After this period leaf nutrient levels may start to decline again, and a negative correlation between leaf nutrient fluctuations and time from last fertilizer application might therefore be expected. In the present study no significant correlations were found with time of fertilizer application, but this may be because there was little variation in this parameter. In the future, frequent leaf samplings should be carried out after application of fertilizers, to detect whether in practice leaf levels do rise and fall significantly as a result of fertilizer applications.
CONCLUSIONS

On coastal soils in West Malaysia, fluctuations in the concentration of P and K in leaf 17 of oil palms have been found to be significantly positively correlated with soil moisture in the month before leaf sampling. This effect is attributed to the influence of soil moisture on the ion diffusion rates of P and K in the soil.

On inland soils in West Malaysia, fluctuations in the concentration of K and Ca in leaf 17 of oil palms have been found to be significantly negatively correlated with rainfall received in the 3 month period before sampling. This effect is attributed to either changes in dry matter production with moisture status, or to leaching of ions from the root zone or from the leaves.

Nutrient fluctuations in leaf 17 of oil palm were not generally found to be related to yield prior to sampling, although a small significant negative correlation with leaf Mg was observed on inland soils. There was insufficient variation in the time of fertilizer applications to determine whether this factor causes significant leaf nutrient fluctuations.

More research is required, involving frequent leaf sampling and measurement of leaf dry matter changes; to further elucidate the causes of fluctuations in the concentration of leaf nutrients in oil palm in West Malaysia.

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SUMMARY

Seasonal fluctuations in the concentration of nutrients in leaf 17 of oil palms were examined in relation to changes in rainfall, soil moisture, yield level and time of fertilizer application, in 19 oil palm fertilizer trials carried out in West Malaysia. On coastal soils, leaf P and K were found to increase with the average level of soil moisture prior to sampling, whilst on inland soils, leaf K and Ca were found to decrease with the average rainfall received prior to sampling and leaf Mg decreased with the yield level prior to sampling. Equations are presented which can be used to correct for these leaf nutrient fluctuations.

REFERENCES


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