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# The effects of nitrogen and potassium on the growth and foliar nutrient levels of immature MAWA coconut palms grown on an ultisol

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Key words: MAWA palms, growth, critical foliar nutrient levels, Rengam series soil, nitrogen, potassium

**Abstrak**

Kesan empat kadar N dan K (1,3,5 dan 7 kg ammonium sulfat dan muriat potasy/pokok setahun) terhadap tumbesaran dan aras nutrien dalam daun bagi kacukan MAWA muda yang ditanam di tanah Siri Rengam telah dikaji antara tahun 1982 hingga 1986. Hanya penggunaan N berkesan ($p = 0.05$) bagi meningkatkan pengeluaran tahunan pelepah. Penggunaan N dan K secara berasingan atau serentak tidak berkesan meningkatkan jumlah pelepah yang ada pada pokok, jumlah daun sepelepah, panjang pelepah dan tinggi pokok.

Peningkatan kadar N berkesan bagi meningkatkan aras N dalam daun. Tindakbalas yang didapati ialah dalam bentuk kuadratik pada tahun ketiga dan keempat. Peningkatan kadar K hanya berkesan ($p = 0.05$) menambah aras K dalam daun. Tindakbalas yang didapati dalam tahun ketiga berbentuk kuadratik tetapi lurus pada tahun keempat semasa kelapa mula berbuah. Aras Mg dalam daun turun ($p = 0.05$) secara lurus apabila kadar K atau N ditingkatkan pada tahun keempat dan hanya kadar K pada tahun ketiga. Tindakbalas N dan K pada tahun ketiga menurunkan ($p = 0.05$) aras Mg.

Aras N dan K dalam daun telah dibandingkan dan aras kritikal N dan K yang lebih munasabah untuk penanaman kelapa di tanah pedalaman tropika disyorkan.

Data daripada kajian awal ini menunjukkan bahawa kadar penggunaan N dan K bagi kelapa MAWA di kawasan pedalaman menunjukkan tindakbalas yang lebih terhadap kandungan nutrien dalam daun berbanding dengan tumbesaran tampang. Pada keseluruhannya kelapa MAWA mempunyai masa depan yang baik.

**Abstract**

The effects of four levels each of nitrogen and potassium (1, 3, 5 and 7 kg/palm per year of ammonium sulphate and muriate of potash) on the growth and foliar nutrient levels in immature MAWA hybrids on Rengam soil were monitored from 1982 to 1986. N applications but not K significantly ($p = 0.05$) increased annual frond production. N and K treatments alone or in combination did not significantly affect the number of fronds retained, number of leaflets/frond, frond length and palm height.

Increasing N application significantly ($p = 0.05$) increased the N-leaf levels. The response was quadratic in both the third and fourth year. Increasing rates of K significantly ($p = 0.05$) increased the foliar K but not

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the N levels. The response was quadratic during the third year and linear in the fourth when the palms came into bearing. Mg-leaf levels decreased significantly ($p$ = 0.05) and linearly to increasing rates of K or in the fourth year but to K only in the third. N applications in the third year interacted with K to decrease ($p$ = 0.05) Mg leaf levels.

A comparison of the foliar N and K levels in this experiment was attempted and more realistic critical levels of N and K for palms grown on tropical inland soil were proposed.

Preliminary data from this study indicate that MAWA palms on inland soil respond to N and K applications, more in foliar nutrient content than in vegetative growth. The general growth of the palms, on the whole, is very promising.

**Introduction**

Coconut has been cultivated in this country for decades. However, research findings based on organized plantings on inland areas in West Malaysia have been lacking. Our knowledge on their nutritional requirements is limited. Most of coconut plantings which are on coastal soils are over 30 years old and receive very little or no fertilizers.

Results of limited experimentation on coconuts in pre-war Malaya indicated negative or no response to fertilization (Belgrave and Lambourne 1933; Wilshaw 1941). Generally, the palms were unselected material grown under poor drainage conditions which on drainage, gave increased yields (Wardlaw and Mason 1936; Kanapathy 1971). Recently with improved cultural practices and fertilization especially with nitrogen, economic responses were obtained in young and mature Talls (Paterson 1968) and in Malayan Dwarfs (Chew and Lee 1971).

The early work and encouraging reports on the newly introduced, more uniform hybrid material like MAWA on coastal clays injected interest into the coconut industry (Vanialingam et al. 1975, 1978; Ng and Chan 1976; Chan 1978). Goh et al. (1982) in their comparative studies of MAWA grown in three different locations showed that growth of immature palms on Rengam series was comparable to that on Selangor series. Based on these reports, there was a change in attitude which was given added impetus by the need to replant the old palms which were intercropped with cocoa, with MAWA which had a higher yield potential. The cultivation of MAWA both as an intercrop and a monocrop has spread to inland areas where previously there were no organized coconut plantings. As part of the overall objective of MARDI to study the performance of MAWA throughout the country, several locations were chosen and trials laid down. This is one of the experiments in this new research area.

**Materials and methods**

MAWA hybrid palms were planted at 9.1 m triangular spacings (138 palms/ha) at Keluang Station in December 1981 to January 1982 on Rengam series soil (Typic Palendult). The area was previously grown with oil palm and tapioca. Physical and chemical data of the soil are given in *Table 1*. The rainfall histogram averaged over 4 years are given in *Figure 1*.

A $4^2$NK factorial trial in randomized block design with four replicates was laid down with plot size of 5 x 4 palms. The six core palms were recorded. Four levels of nitrogen and potassium, viz. 1, 3, 5 and 7 kg/palm per year in the form of ammonium sulphate (21%N) and muriate of potash (60% $K_20$) were studied. The second level is considered the normal rate of fertilizers applied for

Table 1. Physical and chemical analysis of Rengam series soil

| Analysis | Depth of soil (cm) | | |
|---|---|---|---|
| | 0–4 | > 4–26 | > 26–72 |
| Mechanical composition (%) | | | |
| Clay | 32 | 37 | 41 |
| Silt | 18 | 11 | 13 |
| Fine Sand | 16 | 21 | 13 |
| Coarse sand | 34 | 31 | 33 |
| pH | 4.7 | 4.8 | 4.9 |
| C (%) | 1.62 | 1.31 | 0.82 |
| N (%) | 0.12 | 0.10 | 0.07 |
| NaOH-P (ppm) | 72 | 45 | 48 |
| CEC (meq/100 g) | 9.2 | 7.2 | 6.5 |
| Cations (meq/100 g soil) | | | |
| K | 0.26 | 0.12 | 0.14 |
| Ca | 0.24 | 0.17 | 0.15 |
| Mg | 0.32 | 0.22 | 0.28 |

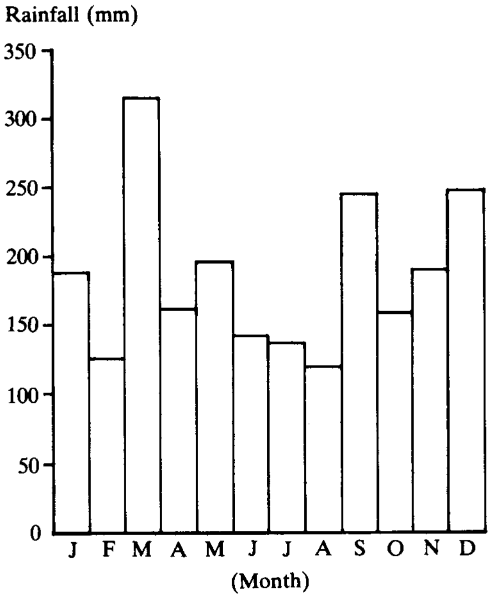


*Figure 1. Monthly rainfall at MARDI Keluang (1983–1986)*

inland mature palms. Fertilizers were applied within the weeded circle in three split applications in the first 2 years and in two applications in the third. Two hundred grams of Christmas Island rock phosphate (36% $P_2O_5$) was incorporated in each planting hole at the time of field planting. Blanket application of rock phosphate and kieserite (26% MgO) at 1 kg/palm per year was done in one and two split applications respectively in subsequent years. Non-experimental palms were applied with 3 kg/yr each of ammonium sulphate and muriate of potash at the same frequency as the experimental palms.

Growth measurements, viz. frond production per year, number of fronds, frond length, number of leaflets per frond, palm height, and foliar sampling to determine nutrient levels, were recorded yearly. This was done in the same month each year, usually more than 3 months after the last fertilizer application. Fronds number 4, 9 and 14 were used for the measurements in the second (1984), third (1985) and fourth year (1986) respectively. Palm height was measured from ground level to the last leaflet of the respective frond in that year.

## Results and discussion

### *Effects of nitrogen and potassium on vegetative growth*

Nitrogen application resulted in significant increase in annual frond production from 1984 to 1986 *(Table 2)*. The trend was more consistent in 1986 where palms which received higher N produced more fronds. There were no consistent and significant differences in the other growth parameters (number of fronds/palm, number of leaflets/frond,

Table 2. Annual frond production

| Level | 1984 | | 1985 | | 1986 | |
|---|---|---|---|---|---|---|
| | N | K | N | K | N | K |
| 1 | 9.2 | 9.1 | 13.2 | 13.5 | 14.0 | 14.4 |
| 2 | 9.4 | 9.7 | 14.0 | 14.2 | 14.6 | 14.7 |
| 3 | 9.9 | 10.3 | 13.9 | 14.0 | 14.8 | 14.6 |
| 4 | 9.8 | 9.6 | 14.5 | 13.9 | 14.9 | 14.6 |
| Mean | | 9.6 | | 13.9 | | 14.6 |
| F-value | * | ns | ** | ns | ** | ns |
| LSD ($p$=0.05) | 0.46 | – | 0.72 | – | 0.47 | – |

*$p$=0.05
**$p$=0.01
ns = not significant

Table 3. Number of fronds/palm

| Level | 1984 | | 1985 | | 1986 | |
|---|---|---|---|---|---|---|
| | N | K | N | K | N | K |
| 1 | 11.7 | 11.5 | 17.5 | 16.8 | 22.2 | 21.1 |
| 2 | 10.9 | 11.6 | 17.0 | 17.5 | 21.2 | 21.7 |
| 3 | 11.4 | 11.0 | 17.1 | 17.3 | 21.8 | 22.4 |
| 4 | 11.2 | 11.1 | 17.2 | 17.2 | 21.8 | 21.8 |
| Mean | | 11.3 | | 17.2 | | 21.7 |
| F-value | * | ns | ns | ns | ns | ns |
| LSD ($p$=0.05) | 0.56 | – | – | – | – | – |

*$p$=0.05

Table 4. Number of leaflets/frond

| Level | 1984 Frond 4 | | 1985 Frond 9 | | 1986 Frond 14 | |
|---|---|---|---|---|---|---|
| | N | K | N | K | N | K |
| 1 | 139.0 | 139.3 | 174.0 | 176.4 | 200.4 | 201.9 |
| 2 | 132.7 | 136.6 | 175.1 | 178.9 | 197.9 | 200.2 |
| 3 | 137.2 | 137.3 | 180.3 | 178.3 | 200.6 | 200.4 |
| 4 | 139.8 | 135.5 | 178.7 | 174.5 | 202.8 | 199.3 |
| Mean | | 137.2 | | 177.0 | | 200.4 |
| F-value | ns | ns | ns | ns | ns | ns |

Table 5. Frond length (cm)

| Level | 1984 Frond 4 | | 1985 Frond 9 | | 1986 Frond 14 | |
|---|---|---|---|---|---|---|
| | N | K | N | K | N | K |
| 1 | 219.4 | 220.6 | 303.1 | 309.6 | 348.0 | 350.2 |
| 2 | 206.1 | 213.9 | 302.1 | 307.8 | 341.6 | 346.9 |
| 3 | 210.8 | 207.8 | 311.5 | 304.6 | 347.7 | 346.8 |
| 4 | 211.9 | 206.0 | 305.4 | 300.1 | 350.4 | 343.9 |
| Mean | | 212.1 | | 305.5 | | 346.9 |
| F-value | ns | ns | ns | ns | ns | ns |

Table 6. Palm height (cm)

| Level | 1984 Frond 4 | | 1985 Frond 9 | | 1986 Frond 14 | |
|---|---|---|---|---|---|---|
| | N | K | N | K | N | K |
| 1 | 135.1 | 134.0 | 192.4 | 200.1 | 238.2 | 242.8 |
| 2 | 123.4 | 129.4 | 192.9 | 195.8 | 237.2 | 243.2 |
| 3 | 127.9 | 127.2 | 198.9 | 193.2 | 243.7 | 248.8 |
| 4 | 128.2 | 124.1 | 194.9 | 190.1 | 251.4 | 235.8 |
| Mean | 128.7 | | 194.8 | | 242.6 | |
| F-value | ns | ns | ns | ns | ns | ns |

Table 7. Comparative growth of 3-year-old palms on Rengam Series

| No. of fronds/palm | Annual frond prod. | Frond (a) length (cm) | No. of leaflets/frond | Palm height (cm) |
|---|---|---|---|---|
| 17.2 | 13.91 | 305.5 | 177.0 | 194.8 |
| 15.5 | 11.50 | 283.0 | 148.5 | 181.2 after Goh (1982) |

frond length and palm height) because of the different levels of N treatment. *(Table 4* to *Table 6).* Only in 1984 that N application decreased the number of fronds retained on the palm *(Table 3).* This effect was not observed in either 1985 or 1986.

The four different levels of K fertilizer had no significant effect on annual frond production or any of the other growth parameters recorded *(Table 2* to *Table 6)* from 1984 to 1986. The addition of K fertilizer did not enhance the N effect on annual frond production. It also did not modify the N effect on the other growth parameters.

Nitrogen applications resulted in more reactions in the palms than K fertilizer. This is because the palms are in the immature phase and N is needed more than K for growth. On the whole, the MAWA palms did not seem to react vigorously to N and K fertilizer applications, in terms of vegetative growth. This could possibly be the low N/K requirement for growth or the less vigorous nature of the roots and above ground parts. However, when a comparison was made between the growth of these palms to similar aged palms as reported earlier by Goh (1982) the palms here are more vigorous and superior in growth *(Table 7).* This could be caused by the high fertilizer rates applied.

***Effect of nitrogen and potassium on foliar nutrient levels***

**Nitrogen effect.** Foliar N levels were greatly increased by nitrogen applications *(Table 8).* Very consistent and significant differences were obtained in each year of recording from 1984 to 1986. Foliar N response to N fertilizer application was quadratic in both 1985 and 1986 *(Figure 2 and Figure 3).* The regression equation that best described foliar N levels = f (N fertilizer rates) was $y = 1.469 + 0.298x - 0.043x^2$ for 1985 and $y = 1.095 + 0.282x - 0.041x^2$ for 1986. The coefficient of determination $R^2$ was 0.714 and 0.769 respectively. When N fertilizer was increased beyond the third level in both years, a decrease in foliar N content resulted. This indicated that additional N fertilizer beyond the third level could lead to wastage as no corresponding increase in foliar N content was detected.

N application had no consistent and significant effect on Ca and K (except for 1984) content in the leaves over the period of recording *(Table 10* and *Table 11).*

Nitrogen application, in 1986 only, resulted in significant differences in Phosphorus and Mg leaf content among

Table 8. Foliar N (%)

| Level | 1984 Frond 4 | | 1985 Frond 9 | | 1986 Frond 14 | |
|---|---|---|---|---|---|---|
| | N | K | N | K | N | K |
| 1 | 1.80 | 1.86 | 1.73 | 1.89 | 1.33 | 1.46 |
| 2 | 1.96 | 1.93 | 1.88 | 1.93 | 1.50 | 1.50 |
| 3 | 1.95 | 1.95 | 1.99 | 1.83 | 1.57 | 1.54 |
| 4 | 2.02 | 1.89 | 1.96 | 1.91 | 1.56 | 1.46 |
| Mean | | 1.93 | | 1.89 | | 1.49 |
| F-value | *** | ns | *** | ns | *** | ns |
| LSD ($p$=0.05) | 0.08 | – | 0.10 | – | 0.09 | – |

***$p$=0.001

Table 9. Foliar P (%)

| Level | 1984 Frond 4 | | 1985 Frond 9 | | 1986 Frond 14 | |
|---|---|---|---|---|---|---|
| | N | K | N | K | N | K |
| 1 | 0.11 | 0.11 | 0.11 | 0.11 | 0.08 | 0.08 |
| 2 | 0.12 | 0.12 | 0.11 | 0.11 | 0.09 | 0.09 |
| 3 | 0.11 | 0.12 | 0.11 | 0.11 | 0.09 | 0.09 |
| 4 | 0.12 | 0.11 | 0.12 | 0.11 | 0.09 | 0.09 |
| Mean | | 0.11 | 0.11 | | | 0.09 |
| F-value | ns | ns | ns | ns | * | ns |
| LSD ($p$=0.05) | – | – | – | – | 0.005 | – |

*$p$=0.05

Table 10. Foliar K (%)

| Level | 1984 Frond 4 | | 1985 Frond 9 | | 1986 Frond 14 | |
|---|---|---|---|---|---|---|
| | N | K | N | K | N | K |
| 1 | 2.32 | 2.16 | 2.03 | 1.81 | 1.36 | 1.11 |
| 2 | 2.19 | 2.24 | 2.13 | 2.09 | 1.35 | 1.34 |
| 3 | 2.24 | 2.25 | 2.08 | 2.16 | 1.34 | 1.41 |
| 4 | 2.18 | 2.28 | 2.03 | 2.20 | 1.34 | 1.52 |
| Mean | | 2.23 | | 2.07 | | 1.35 |
| F-value | * | ns | ns | *** | ns | *** |
| LSD ($p$=0.05) | 0.10 | – | – | 0.11 | – | 0.16 |

*$p$=0.05
***$p$=0.001

Table 11. Foliar Ca (%)

| Level | 1984 Frond 4 | | 1985 Frond 9 | | 1986 Frond 14 | |
|---|---|---|---|---|---|---|
| | N | K | N | K | N | K |
| 1 | 0.23 | 0.22 | 0.23 | 0.23 | 0.31 | 0.32 |
| 2 | 0.23 | 0.22 | 0.21 | 0.21 | 0.32 | 0.31 |
| 3 | 0.24 | 0.24 | 0.22 | 0.22 | 0.31 | 0.31 |
| 4 | 0.22 | 0.24 | 0.22 | 0.22 | 0.29 | 0.28 |
| Mean | | 0.23 | | 0.22 | | 0.31 |
| F-value | ns | ns | ns | ns | ns | ns |

*N* response equations

$y = 1.769 + 0.066x$ $y = 1.469 + 0.298x - 0.043x^2$

$R^2 = 0.617^{**}$ $R^2 = 0.714^{***}$

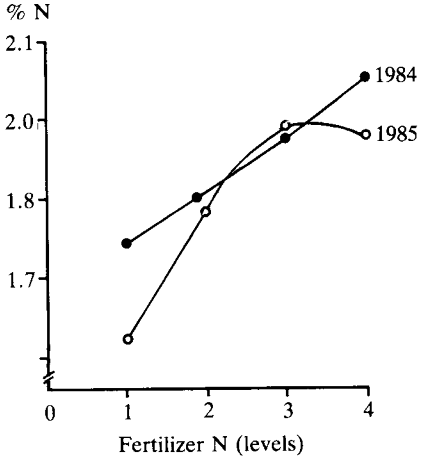


*Figure 2. Foliar N response to N fertilization (1984 and 1985)*

N response equations Mg response equation

$y = 1.095 + 0.282x - 0.041x^2$ $y = 0.196 - 0.014x$

$R^2 = 0.759^{***}$ $R^2 = 0.407^{**}$

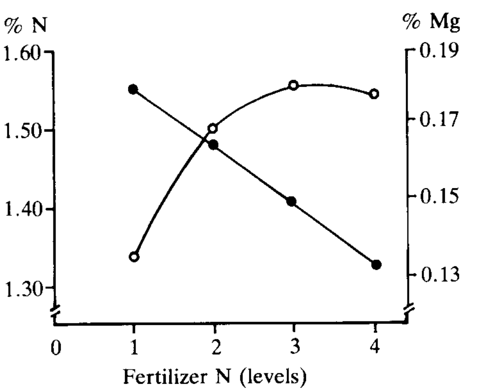


*Figure 3. Foliar N and Mg response to N fertilization (1986)*

the various treatments *(Table 9* and *Table 12)*. The regression of foliar P content on N fertilizer levels was quadratically significant ($p = 0.05$) and their relationship could be expressed mathematically as $y = 0.074 + 0.011x - 0.002x^2$ with coefficient of determination $R^2 = 0.419$. Increasing rates of N depressed ($p = 0.05$) Mg leaf content in a linear fashion *(Figure 3)*. Their relationship could be described by the regression equation of $y = 0.196 - 0.015x$ with $R^2 = 0.407$. The linear decrease in Mg foliar content in 1986 due to N fertilizer applications could be due to dilution effect as there was a very significant increase in annual frond production in 1985 and 1986, Mg supply being limited.

**Potassium effect.** The K fertilizer applications had resulted in consistent and significant differences in foliar K and Mg contents in 1985 and 1986. *(Table 10* and *Table 12)*. Increasing potassium application up to the third level in 1985 had increased the percentage foliar K content. Beyond that, a peak in foliar K content was observed *(Figure 4)*. The regression of foliar K content on K levels was quadratically significant and their relationship best expressed as $y = 1.444 + 0.433x - 0.061x^2$.

K response equation

$y = 1.444 + 0.433x - 0.061x^2$

$R^2 = 0.853^{***}$

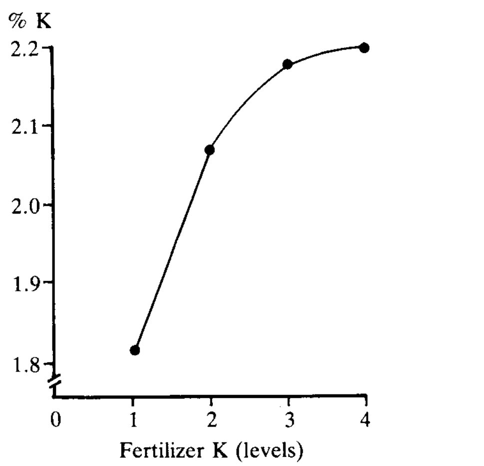


*Figure 4. Foliar K response to K fertilization (1985)*

However in 1986, the relationship was linear up to the fourth level *(Figure 5)*. The highest foliar K level was 1.53% which was considerably lower than the peak of 2.21% K in 1985.

This suggested that the amount of K fertilizer applied even up to the fourth

Table 12. Foliar Mg (%)

| Level | 1984 Frond 4 | | 1985 Frond 9 | | 1986 Frond 14 | |
|---|---|---|---|---|---|---|
| | N | K | N | K | N | K |
| 1 | 0.17 | 0.18 | 0.15 | 0.15 | 0.18 | 0.18 |
| 2 | 0.17 | 0.17 | 0.13 | 0.13 | 0.16 | 0.16 |
| 3 | 0.16 | 0.17 | 0.14 | 0.13 | 0.15 | 0.16 |
| 4 | 0.17 | 0.16 | 0.13 | 0.13 | 0.14 | 0.14 |
| Mean | | 0.17 | | 0.14 | | 0.16 |
| F-value | ns | ns | ns | * | ** | ** |
| LSD ($p$=0.05) | – | – | – | 0.01 | 0.02 | 0.02 |
| NK Interaction | – | – | | * | – | – |

*$p$=0.05

Table 13. Proposed critical foliar levels for MAWA (after Manciot et al. 1979)

| Age (year) | Frond no. | %Dry matter | | | |
|---|---|---|---|---|---|
| | | N | P | K | Mg |
| 1 | 1 | 1.7 | 0.16 | 3.0 | 0.27 |
| 2 | 4 | 2.2 | 0.14 | 2.0 | 0.24 |
| 3 | 9 | 2.2 | 0.13 | 1.7 | 0.23 |
| 4 | 14 | 2.2 | 0.12 | 1.5 | 0.21 |
| 5 | 14 | 2.2 | 0.12 | 1.4 | 0.20 |

K response equation

$y$=1.020 + 0.130$x$
$R^2$= 0.835***

Mg response equation

$y$= 0.191 − 0.013$x$
$R^2$= 0.310*

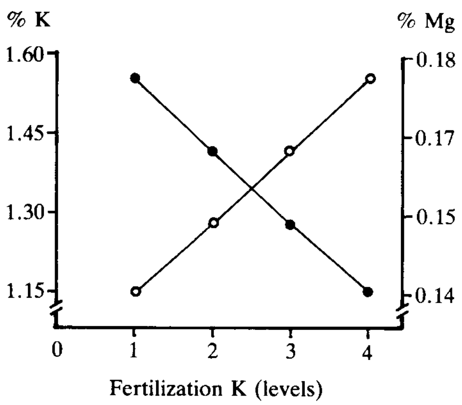


*Figure 5. Foliar K and Mg response to K fertilization (1986)*

level and soil K supply were inadequate to meet the palms' demand. The MAWA palms at the fifth year of growth require a vast supply of K as they come into production (fruiting) and maturity stage.

Increasing the rates of K application significantly depressed ($p$ = 0.05) the foliar Mg content in 1985 and 1986 *(Table 12)*. Their linear relationship in 1986 could be expressed by the regression equation of $y$ = 0.191 − 0.013 $x$ *(Figure 5)*. The antagonistic effect of K on Mg is clearly apparent in this study.

**Comparison with proposed critical foliar levels**

Comparison of these foliar N and K levels in this experiment with the critical levels for MAWA palms as proposed by Manciot et al. (1979) in *Table 13* showed that the N levels were always lower, from the second to the fourth year of age *(Table 8)*.

Foliar K levels were consistently higher for the second and third year of growth for all the four levels of fertilizer application *(Table 10)*. In the fourth year (1986), only the palms which received the highest level of K application had foliar K content which exceeded the proposed critical level.

The MAWA palms responded to N application by producing significantly more fronds/annum *(Table 2)* and had higher foliar N levels *(Table 8)*. The foliar N response in the second year was linear but quadratic in the third and fourth year which indicated falling response to higher N applications *(Figure 2* and *Figure 3)*. For these reasons, the proposed critical N level for these 2 years at 2.2% by Manciot et al. (1979) is too high. From *Figure 2* and *Figure 3*, the maximum foliar N level is about 2.0% and 1.58%, beyond which the response curve declined. Under Malaysian inland conditions, realistic critical foliar N levels for 3 and 4-year-old MAWA palms would be 2.0% in frond 9 and 1.58% in frond 14 respectively.

The different levels of K applied did not affect the growth of MAWA palms as measured by the various vegetative parameters. Foliar nutrient levels which were affected were K and Mg in both 1985 and 1986 *(Table 10* and *Table 12)*. Potassium applications in 1985 produced a quadratic response in leaf K levels while it was linear in 1986 *(Figure 4* and *Figure 5)*. In 1985, the maximum foliar K level was 2.2% which indicated that the critical K level could be 2.2% for 3–year old and definitely higher than 1.55% for 4–year old MAWA palms.

The proposed critical N and K foliar levels here for MAWA on inland soil are more accurate than those of Manciot et al. (1978) because they are specific for inland soil and obtained through sound experimentation. On the other hand, Manciot et al. (1979) based their figures on unpublished trials sited on sandy soils in Ivory Coast.

**Conclusions**

Nitrogen applications significantly increased the annual frond production of young MAWA palms grown on Rengam series soil. Other growth parameters like frond length, number of leaflets/frond and palm height were not responsive to the different levels of N application. Potassium application had no interaction with N in annual production of fronds or any other growth parameters.

Application on N and K significantly increased the foliar N and K content of the young MAWA palms respectively. The antagonistic effect of K application on foliar Mg content was demonstrated in this experiment.

Comparison of the foliar N and K levels to that proposed by Manciot et al. (1979) showed that nitrogen levels were always lower. Potassium levels were higher in the second and third year of growth but lower in the fourth when the palms came into bearing. These critical levels for N and K obtained in this experiment would be more accurate for tropical inland soils.

The experiment would be continued to determine the effects of N and K on yield and foliar nutrient levels at the mature stage when P and Mg fertilizer rates would be increased.

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