

OIL PALM NUTRITION

M. ACHUTHAN NAIR* and C. SREEDHARAN

*College of Agriculture
Vellayani 695 522, Trivandrum, India.*

ABSTRACT

The results of fertiliser experiments conducted in the major oil palm growing countries of the world are reviewed here. The review mainly deals with the effect of major nutrients like N, P, K, Ca and Mg on the growth, yield and tissue concentration of oil palm.

INTRODUCTION

Field experiments to study the effect of major and secondary nutrients on the growth and productivity of oil palms have been carried out in the main oil palm growing countries of the world like Malaysia, Nigeria, Indonesia, Ghana, Ivory Coast, Cameroon and Dahomey. Several workers reviewed oil palm nutrition and fertiliser requirements in relation to soil and climatic factors existing in the major oil palm growing countries from time to time (May, 1956; Broeshart, 1957; Rosenquist, 1962; Hew and Ng, 1968; Ollagnier, Ochs and Martin, 1970; Hew, Ng and Lim, 1973; Lo et al., 1973; Tan, 1973; Warriar and Piggot, 1973; Foster and Chang, 1976 and Hartley, 1977). This compilation covers an updated comprehensive review on the nutritional aspects of oil palm in the world.

NUTRIENT REMOVAL BY OIL PALM

The nutrient removal of oil palms in twenty years in Nigeria was 460, 160, 340, 260 and 234 kg N, P, K, Mg and Ca per hectare respectively (Tinker and Smilde, 1963) whereas in Malaysia the removal was 960, 80, 1300, 290 and 40 kg N, P, K, Mg and Ca per hectare respectively (Ng, 1968). According to Ollagnier et al. (1970) the nutrient removal of oil palms was 30, 7, 18, 13 and 10 kg N, P, K, Ca and Mg per hectare per year respectively. According to Ng (1976) the estimated annual uptake of N, P, K and Mg by 8-10 year old palms was 192.5, 26.0, 251.5 and 61.3 kg per hectare respectively.

Tinker and Smilde (1963) estimated the N, P, K and Mg requirements of oil palm plantations in Nigeria yielding 9.6 tonnes of fresh fruit

* Present Address: Central Plantation Crops Research Institute, Research Centre, Palode Pacha 695 562, Trivandrum.

bunches per hectare per year and found to be 0.20, 0.04, 0.23 and 0.03 kg per palm per year respectively. Under Malaysian conditions N, P, K and Mg requirements were 0.49, 0.08, 0.63 and 0.14 kg respectively per palm per year (Ng and Thamboo, 1966) for a plantation yielding 15 tonnes per hectare.

EFFECT OF FERTILISERS ON GROWTH, YIELD ATTRIBUTES AND YIELD

Nitrogen

Nitrogen exerts a major role in controlling the growth and fruiting of oil palm and it is commonly required for rapid growth of oil palm in the field (Hartley, 1977).

Rosenquist (1962) and Corley and Mok (1972) reported a higher rate of leaf production and total number of leaves per palm with increased nitrogen application. Tan (1973) found that in inland soils of Malaysia, out of three levels of nitrogen fertilisers tried, the middle level of 0.36 kg of Nitro-26 (26%N) per palm gave the highest number of leaves. Breure and Rosenquist (1976) could not get a significant effect on frond production in the volcanic soils of Papua New Guinea. They, in fact noted a reduction in frond production with 1.5 kg urea application per palm per year.

Beirnaert (1935) found that female flower production was decreased by nitrogen application due to high photosynthetic activity or high C/N ratio of plants. Sparnaaij (1960) supported this view and opined that increase in nitrogen application reduced sex ratio.

Nair (1981) also reported similar results.

Warriar and Piggot (1973) observed that number of bunches and weight of bunches increased in plots with N fertilisation. They found that bunch number and bunch weight were higher in plots treated with 12.2 lb of N, 10.6 lb of P, 25.4 lb of K and 2.7 lb of Mg. Tan (1976) noted bunch abortion in treatments receiving 6.78 kg of ammonium sulphate.

Several workers like Van der Vossen (1970), Green (1972), Tan (1976) and Nair (1981) got favourable responses to nitrogen application in the yield of oil palm.

Tan (1973) reported that application of Nitro-26 at 0.54 kg per palm per year gave consistently and significantly higher weight of FFB compared with lower levels. Optimum yield in oil palm was obtained with an application of 3 kg of sulphate of ammonia per palm per year (Anonymous, 1974).

Hew et al. (1973) could get yield response from the sixth year with 3.2 kg Nitro-26 with an average yield of 3.87 tonnes per hectare per year in the Munchung series soils of Malaysia. They further noted that in Bria series soils, there were significant responses to the application of 1.8 kg of Nitro-26 from the sixth year and it was also found that the nitrogen response in yield increased with the age of palms.

Breure and Rosenquist (1976) found that urea application had no significant effect on yield of oil palm in volcanic soils of Papua New Guinea,

during early bearing stages. But during later stages, N produced a positive effect on yield. Umar Akbar et al. (1976) reported that the effect of N in yield was only 10% in the early years and thereafter increased to 40%. They noted that application of 4 kg of ammonium sulphate increased the bunch yield by 44 kg per palm which was 43% higher than the yield from palms which did not receive nitrogen. Nair (1981) reported significant increase in yield with the application of 800 g N/palm/year in the lateritic soils of Kerala.

However, Bachy (1968) and Mollegaard (1971) did not find response to N fertilisation in yield of oil palms.

Phosphorus

Comhaire (1968) regarded phosphorus manuring as pivotal in oil palm fertilisation. According to Ollagnier et al. (1970) phosphorus is required for full expression of qualitative characters in oil palm. Experiments in Africa showed that P was needed only after several years of bearing (Hartley, 1977).

Tan (1976) obtained significantly higher number of fronds with rock phosphate at 1.36 kg/palm per year compared with 0.68 kg and 2.72 kg/palm.

Mollegaard (1971) reported that rock phosphate significantly increased number of bunches and bunch weight. He further noted that production of male inflorescence was also significantly higher under P fertilisation. Tan (1976) observed significantly higher number of

undeveloped bunches under lowest level of P.

Chapman and Gray (1949) from Ivory Coast, got positive and relatively constant responses to phosphatic manures upto 17% in a 12 year old plantation and 9% in a 13-17 year old plantation. Rosenquist (1962) also got response to P upto 2.7 kg of rock phosphate per palm per year, in soils derived from granite. Werkhoven (1965) obtained yield increase of 12-20 tonnes/ha by P application in the volcanic soils of Sumatra. Bachy (1968) got response to dicalcium phosphate at 2 kg/palm/year when the soil P was very low. Mollegaard (1971) obtained substantial yield increase in the colluvial alluvial soils of Malaysia with 3.8 kg of rock phosphate per palm per year. Lo et al. (1973) showed that the lowest level of P fertilisation (5 lb/palm) had produced the highest yield in soils derived from granite. Tan (1976) reported that rock phosphate application at 2.72 kg/palm gave better response. Umar Akbar et al. (1976) got a production of 34 kg bunches with 3 kg superphosphate per palm per year, which was 32% more than control. Nair (1981) got significant yield increase for 400 g P_2O_5 per palm per year.

Van der Vossen (1970) from Ghana observed that application of single superphosphate at 4.54 kg/palm gave increased yield over control. Green (1972) stated that in Cameroon, soils derived from basaltic flows, P response was obtained in early growth stages. Foster and Goh (1976) showed that P application was profitable in all soils, except alluvium and peat in Malaysia.

According to Hartley (1977) P is required in specific soils and produced large increases in yield in such soils.

However, on examination of results from Zaire, Vanderweyen (1952) found a lack of response to P and suggested that it was due to P fixation in soils. Dell and Arens (1957) could not get response to P dressing in certain types of Sumatran soils. In areas previously cropped by grass vegetation, there was no response to P and a response at 2 kg/palm of dicalcium phosphate was obtained when the soil P was very low (Bachy, 1968). Experiments conducted at the United Plantations in Malaysia did not show response to P application at 2.7 kg/palm/year of rock phosphate (Hartley, 1977). Breure and Rosenquist (1976) also got no effect on yield with application of disodium phosphate.

Potassium

Ollagnier et al. (1970) concluded that K was the fundamental element in the manuring of oil palms and observed its requirement to the crop under various situations. Hartley (1977) also found K as the most commonly required element in oil palm nutrition.

Tan (1973) reported that in Malaysia, application of 3.63 kg of muriate of potash per palm produced highest number of leaves. He observed that maximum potassium would be required for frond production.

Mollegaard (1971) found that potash application increased the male flower production and consequently low

sex ratio. He further noted increased bunch weight and bunch number with K fertilisation.

Corley and Mok (1972) in Rengam soils of Malaysia recorded increase in dry matter of production, leaf area index and crop growth rate by K application.

Response to K fertilisation in oil palm yield were also reported by many workers. Bachy (1968) from Ivory Coast reported that application of one kg of potassium chloride per palm per year had increased the yield from 17 to 82 kg in Savannah soils. He also found that when the quantity of muriate of potash was increased to 2 kg per palm per year, the yield increased upto 98 kg/palm, which was 58% more than zero potassium. Hew and Poon (1973) reported responses to potassium chloride in the marine clays. In Malaysia, Hew et al. (1973) got linear increase for K dressing up to 2.5 kg potassium chloride per palm per year. de Taffin and Ochs (1973) recommended 0.75 kg potassium chloride per palm per year in K deficient Dahomey soils. Breure and Rosenquist (1976) reported that muriate of potash had significantly increased the yield and the production had reached 17% of FFB by the fourth year of yield. Tan (1976) reported that muriate of potash at 5.46 kg/palm/year produced significantly higher yield in the early stages. But after the ninth year, muriate of potash at 2.73 kg/palm gave the highest yield. Nair (1981) reported significantly increased yield with 1.8 kg of K_2O per palm per year in an eight year old plantation.

Calcium

Published literature on the calcium nutrition of oil palm is very meagre. Ollagnier et al. (1970) in their review on the manuring of oil palms in the world mentioned that not much work has been done on the calcium nutrition of oil palm. However, one experiment conducted at the United Plantations in Malaysia showed that there was an increase in yield to the extent of 10% by application of calcium (Hartley, 1977). The experiments conducted by Nair (1981) however showed lack of response to calcium.

Magnesium

Magnesium as a constituent of chlorophyll has an important role to play in the physiology and yield of oil palm.

Breure and Rosenquist (1976) reported that the frond production in oil palm increased by magnesium chloride application. Chan and Rajaratnam (1976) observed that female flower production was not influenced by magnesium application in forest soils. Similar results were obtained by Nair (1981) also. Tan (1976) observed more number of aborted bunches at higher levels of magnesium.

Yield improvement resulting from application of magnesium to deficient palms was observed by Ferwerda (1955) in Ivory Coast. Gunn (1962) found response for 3.41 kg/palm/year of magnesium sulphate. Application of 1 kg kieserite per palm per year was found to respond well in oil palm (Green, 1972). A cumulative yield of 35.58 tonnes/ha in four years with 2.72

kg of magnesium sulphate per palm per year was obtained in Nigeria (Anonymous 1972). Experiments on young palms in Peru, revealed that magnesium chloride application increased the yield significantly (Daniel and Ochs, 1975).

However, lack of response to magnesium fertilisation in oil palm has also been reported by many workers. Very low and irregular response to magnesium application in young as well as old palms were reported from Nigeria (Anonymous, 1966). Van der Vossen (1970) did not get response to magnesium sulphate at 2.72 kg/palm/year in Ghana. Hew and Poon (1973) could not get yield response in acid soils of Malaysia by Magnesium application. Hew et al. (1973) and Lo et al. (1973) also reported lack of response to magnesium in oil palm. Chan and Rajaratnam (1976) while reviewing the results on magnesium requirements of oil palm in Malaysia, concluded that response to magnesium was invariably obtained only after 23 years of growth of palms in forest soils.

NUTRIENT INTERACTIONS

The studies conducted with various nutrients in oil palm revealed that full expression of one nutrient was obtained when other nutrients were supplied in adequate quantities.

Dell and Arens (1957) got positive interaction of N and P. They got 40% increase in yield by application of N and P individually while 100% increase in yield was recorded by N×P combination. Vanderweyen (1952) reported instance of negative response to P in the absence of K fertilisers.

Rosenquist (1962) observed that responses to N were dependent on an adequate supply of P and K. High P application caused the N effect to be negative and vice-versa. When K was sufficient, response to N was positive at all levels of P. He also noted that K alone had no significant response even at the highest level of P. Mollegaard (1971) showed that the highest rate of P application gave significant increase in yield only in the presence of K fertilisation.

Tan (1973) found that NP and PK interactions gave the most favourable effect on characters like frond production and yield of oil palm. Chan and Rajaratnam (1976) found that Mg was necessary for full expression of N and K on yield.

Green (1972) obtained response to P and K in lateritic soils, with P \times K interaction and a further yield increment by N and Mg.

EFFECT OF FERTILISERS ON TISSUE CONCENTRATION

Leaf analysis for diagnostic purposes can be successfully made use of in perennial crops where responses to fertilisation will take a longer time (Hartley, 1977). In regions where water deficits occur, proper nutrient requirements can be assessed based on tissue content of elements.

Prevot and Ollagnier (1959) found an increase in leaf N content by N fertilisation. Ollagnier et al. (1970) reported that leaf N increased from 2.30 to 2.70% by N application. Warriar and Piggot

(1973) reported a high concentration of tissue N in fertilised plots. According to Hartley (1977) N application increased leaf N.

An increase in leaf P with N application was observed by Chapman and Gray (1949). Ollagnier et al. (1970) also found an appreciable increase in leaf P by N application. Umar Akbar et al. (1976) found increased K level with higher N fertilisation. Hartley (1977) stated that N application resulted an increase in P, decrease in K and Mg in leaves, whereas there was no marked effect on leaf Ca. Nair (1981) found that N fertiliser increased the leaf N, P, K, Ca and Mg contents and reduced leaf chlorine content. He got higher yield when the leaf N content increased from 2.36% to 2.68%.

Prevot and Ollagnier (1959) reported that when the leaf N content reached 2.70%, there was a positive correlation between K levels and yield. Forde, Leyritz and Sly (1965) got responses to yield at a level of 2.40%. Ollagnier et al. (1970) reported an yield increase of over 50% when the leaf N concentration was increased from 2.30 to 2.70%. Warriar and Piggot (1973) also got similar results. Foster and Chang (1976) got an yield increase of one tonne per hectare of FFB by an enhancement of leaf N content by 0.03-0.5%. Response to N was also obtained in palms where leaf N content was about 2.60% (Umar Akbar et al., 1976).

Forde et al. (1965) found that P application helped to increase P content of tissues. Warriar and Piggot (1973) observed a low tissue P when P

fertilisers were not applied. Hartley (1977) reported that P application enabled to increase the P and Ca contents in the leaf and decreased the leaf K. Similar results were obtained by Nair (1981). Further he reported an increase in leaf N and Mg contents by P fertilisation. Forde et al. (1965) obtained yield increase to leaf P content of 0.147%. Ollagnier et al. (1970) obtained response to phosphorus only when the tissue P content was higher than 0.150%. Reports of yield increment of about 32% by an increase in leaf P was reported by Green (1972). Foster and Chang (1976) in Malaysia got an yield increase of one tonne/ha by an increase in the P level by 0.003-0.005%. But Bachy (1969) could not get any increase in yield with increased leaf P content, at Ivory Coast. Nair (1981) showed positive correlation between leaf P content and yield of oil palm.

Warriar and Piggot (1973) found very low levels of leaf K in the absence of K fertilisers. They got an increase in tissue K content only when KCl was applied. Hartley (1977) observed that K fertilisation eventhough helped to increase leaf K, produced an antagonistic effect on Ca and Mg. At the same time, K application showed no marked effect on leaf N and P.

Chapman and Gray (1949) noted that K application resulted in an increased uptake of nitrogen. The relation between P and K contents in tissue was reported by Ochs (1965). He found that when leaf P was less than 0.15%, there was no correlation between leaf K and yield. When leaf P content was

brought upto 0.15%, there was strong correlation between leaf K and yield. He further noted that when K level was below 1%, there was no correlation between P and yield, but when leaf K was about 1%, there was strong correlation between leaf P and yield.

Prevot and Ollagnier (1959) noted that when leaf K level was more than 1%, there was significant positive correlation between N and yield. Ochs (1965) found that yield was raised by 4-12% for every gain of 0.1% of K level in the leaf. He showed that yield decreased linearly as the leaf level of K declined below its optimum concentration. Forde et al. (1965) obtained yield improvement of individual palms with a leaf K content of 1.20%.

Bachy (1969), Warriar and Piggot (1973) and Nair (1981) got increased yield, when the leaf K content was increased.

Ollagnier et al. (1970) showed that the response of K was very closely linked with the K content in the leaf, particularly when this level was below critical level. Foster and Chang (1976) in Malaysia, got an yield increase of one tonne FFB/ha by an increase in tissue K content by 0.5-0.8%. Nair (1981) reported an increase in mean yield when the tissue K level rose from 0.85% to 0.94%.

Hartley (1977) showed that Ca fertilisation did not have any effect on N, P and Mg concentration in leaf. However, a decrease in leaf K and increase in leaf Ca was also noticed. Magnesium application on the other

hand decreased leaf P, K and Ca, whereas it enhanced Mg content. Nitrogen content of leaf was not influenced by Mg application. Umar Akbar et al. (1976) reported that raising Mg levels to 0.19% helped to increase the yield by 41%.

Chan and Rajaratnam (1976) reported that Mg tended to increase leaf N. Similarly, application of Mg gave only small decrease in leaf K. They further observed that Mg requirements in oil palms can easily be increased by heavier application of N and P fertilisers. There was no increase in FFB per palm when there was an increase in the leaf Mg content. They further noted that there was no Mg response, if the leaf levels were in excess of 0.20-0.22%. Umar Akbar et al. (1976) reported lowering of K content with Mg application.

Recently the importance of chlorine in the nutrition of palms has been highlighted by Hartley, (1971); Ollagnier and Ochs, (1971) and Ollagnier et al. 1976.

According to Ollagnier and Ochs (1971), chlorine can be considered as an essential element for oil palm mineral nutrition. They noted this on the study of K nutrition, as the intervention of chlorine and linked to the value of yield increases by correcting deficiency. The correlation between chlorine levels and yields enabled the effect of KCl to be attributed to chlorine and not to potassium. According to Ollagnier (1973) study of the correlation between the levels of chlorine and cations in oil palm leaves showed that Cl content

was often in positive correlation with a cation. This can be related to the part played by chlorine in metabolic functions and the main role of chlorine is attributed to absorption of cations.

Prevot and Ollagnier (1954) studied the connection between leaf Ca, Mg and K contents as a function of foliar K and found that the sum of K + Ca + Mg remained at 2% in the 17th leaf, whatever be the nutritional balances between them. Antagonisms between K and Ca + Mg was also exhibited. A decrease in K content was indicative of not only of low K content but also of higher Mg and Ca contents above critical level. An excess of K in leaf would lead to a corresponding fall in Ca and Mg levels.

Broeshart (1955) found a quantitative relationship between the cations in the leaf. The K in tissue was accounted for 60% and Ca was accounted for 30%. Grunder (1960) and Bachy (1965) were of the opinion that for optimal growth and yield of oil palm, the sum of Ca + Mg + K should be around 2.7% of the dry matter and 67-70% of this should be K alone.

CONCLUSION

The review on the nutrition of oil palm in the oil palm growing countries of the world revealed that response to N and K are universal and the above nutrients exert a major role in the growth and production of the oil palm. Phosphorus is required for full expression of qualitative characters and P response depends mainly on P status of the soil. Investigations on the Ca nutrition are meagre and the influence

of Ca on oil palm has not yet been established. Response to Mg fertilisers is generally observed only after several years of growth of oil palm in forest soils. Based on the work done, a fertiliser schedule of 800:400:1800g of N, P₂O₅ and K₂O respectively per palm per year can be recommended for oil

palms in Kerala. The range of leaf nutrient contents for palms nearing steady bearing under Kerala condition is as follows: Nitrogen 2.3 - 2.5%, Phosphorus 0.13 - 0.15%, Potassium 0.85 - 0.94%, Calcium 0.60 - 0.70% and Magnesium 0.25 - 0.30%.

REFERENCES

- ANONYMOUS. 1966. *Annual Report 1966-67*. Nigerian Institute for Oil Palm Research, Benin city, Nigeria. pp. 39.
- *ANONYMOUS. 1972. *Annual Report for 1968-69*, Nigerian Institute for Oil Palm Research. Benin city, Nigeria. pp. 33.
- *ANONYMOUS. 1974. *Rapport d'activités 1972-73*. Institut De Recherches Pour Les Huiles Et. Oleagineux, Paris, France. Document 1138.
- BACHY, A. 1965. Influence de l'éclaircie naturelle sur la production de palmier à huile. *Oleagineux*. 20: 575-577.
- BACHY, A. 1968. Principaux résultats acquis par I. R. H. O. Sur la fertilisation du palmier à huile. *Oleagineux*. 23: 9-14.
- BACHY, A. 1969. A propos d'un cas typique de carence potassique du palmier à huile en Côte d'Ivoire. *Oleagineux*. 24: 533-540.
- BEIRNAERT, A. 1935. Introduction à 'la biologie florale du palmier à huile. *Rev. int. Bot. appl. Agric. Trop.* 15: 1091.
- BREURE, C. J. and ROSENQUIST, E. A. 1976. An oil palm fertiliser experiment in volcanic soils in Papua New Guinea. pp. 327-341. In *International Developments in Oil Palm*. eds. D. A. Earp and W. Newall, Incorporated Society of Planters, Kuala Lumpur.
- *BROESHART, H. 1955. The application of foliar analysis in oil palm cultivation. M.Sc. thesis. Agric. University of Wageningen, The Netherlands.
- BROESHART, H. 1957. The application of foliar diagnosis to oil palm cultivation. IV. The diagnosis of multiple deficiencies. *Trop. Agricult.* 34: 262-276.
- CHAN, K. W. and RAJARATNAM, J. A. 1976. Magnesium requirement of oil palms in Malaysia. 45 years of experimental results. pp. 371-388. In *International Developments in Oil Palm*. eds. D. A. Earp and W. Newall, Incorporated Society of Planters, Kuala Lumpur.
- in *Oil Palm*. eds. D. A. Earp and W. Newall, Incorporated Society of Planters, Kuala Lumpur.
- CHAPMAN, G. W. and GRAY, H. M. 1949. Leaf analysis and the nutrition of the oil palm. *Ann. Bot.* 13: 415-433.
- COMHAIRE, M. 1968. *La fumure du palmier à huile*. Centre Nat. d'Infor. et de Doc. der. Prod. de. Phosphates Thomas. Bruxelles, pp. 161.
- CORLEY, R. H. F. and MOK, C. K. 1972. The effects of nitrogen, phosphorus, potassium and magnesium on growth of the oil palm. *Expl. Agric.* 8: 347-353.
- DANIEL, G. and OCHS, R. 1975. Amélioration de la production des jeunes palmiers à huile du person par l'emploi d'engrais chlore. *Oleagineux*. 30: 295-298.
- DELL, W. and ARENS, P. L. 1957. Inefficacité du phosphate naturel pour le palmier à huile sur certains sols de Sumatra. *Oleagineux*. 12: 657-683.
- de TAFFIN, G. and OCHS, R. 1973. La fumure potassique du palmier à huile au Dehomey. *Oleagineux*. 28: 269-273.
- *FERWERDA, J. D. 1955. Questions relevant to replanting in oil palm cultivation. M.Sc. Thesis. University of Wageningen, The Netherlands.
- FORDE, St. C. M., LEYRITZ, M. J. P. and SLY, J. M. A. 1965. The role of potassium in the nutrition of oil palm in Nigeria. *J. Niger. Inst. Oil palm Res.* 4: 333-369.
- FOSTER, H. L. and CHANG, K. C. 1976. The diagnosis of the nutrient status of oil palms in West Malaysia. pp. 290-312. In *International Developments in Oil Palm*. eds. D. A. Earp and W. Newall, Incorporated Society of Planters, Kuala Lumpur.

- FOSTER, H. L. and GOH, H. S. 1976. Fertiliser requirements of oil palm in West Malaysia. pp. 234-261. In *International Developments in Oil Palm*. eds. D. A. Earp and W. Newall. Incorporated Society of Planters, Kuala Lumpur.
- GREEN, A. H. 1972. The manuring of oil palm in the field - past results. *Oleagineux*. 27: 419-423.
- GRUNDER, G. 1960. The role of potassium in the nutrition of oil palm. *World Crops*. 12: 435-437.
- GUNN, J. S. 1962. The economics of manuring the oil palm. *J. W. Afr. Inst. Oil palm Res.* 3: 302-307.
- HARTLEY, C. W. S. 1971. Chlorine in the nutrition of the oil palm. *Oil palm News*. 12: 1-3.
- HARTLEY, C. W. S. 1977. *The Oil palm*. 2nd ed. Longman, London. PP. 806.
- HEW, C. K. and POON, Y. C. 1973. The effects of muriate of Potash and bunch ash on uptake of potassium and chlorine in oil palms on coastal soils. pp. 239-247. In *Advances in oil palm cultivation*. eds. R. L. Wastie and D. A. Earp. Incorporated Society of Planters, Kuala Lumpur.
- HEW, C. K. and NG, S.K. 1968. A general schedule for manuring oil palms in West Malaysia. *Planter*. 44: 417-429.
- HEW, C. K., NG, S. K. and LIM, K. P. 1973. The rationalisation of manuring of oil palms and its economics in Malaysia. pp. 306-323. In *Advances in Oil Palm Cultivation*. eds. R. L. Wastie and D. A. Earp. Incorporated Society of Planters, Kuala Lumpur.
- LO, K.K., CHAN, K.W., GOH, K.H. and HARDON, J. J. 1973. Effect of manuring on yield, vegetative growth and leaf nutrient level of the oil palm. pp. 324-337. In *Advances in Oil Palm Cultivation*. eds. R. L. Wastie and D. A. Earp. Incorporated Society of Planters, Kuala Lumpur.
- MAY, E. B. 1956. The manuring of oil palms. A review. *J. W. Afr. Inst. Oil Palm Res.* 21: 6-46.
- MOLLEGAARD, H. 1971. Results of fertiliser trial on mixed colluvial alluvial soil at Ulu Beram estate in West Malaysia. *Oleagineux*. 26: 449-453.
- NAIR ACHUTHAN, M. 1981. Nutritional Studies on oil palm *Elaeis guineensis* Jacq. Ph. D. thesis. Kerala Agricultural University, Trichur, India, pp. 110.
- NG, S. K. 1968. Nutrient contents of oil palms in Malaya. II. Nutrients in vegetative tissues. *Malay. Agric. J.* 46: 332-391.
- NG, S. K. 1976. Review of all oil palm nutrition and manuring - scope for greater economy in fertiliser usage. pp. 209-233. In *International Developments in Oil palm*. eds. D. A. Earp and W. Newall. Incorporated Society of Planters, Kuala Lumpur.
- NG, S. K. and THAMBOO, S. 1966. Prospects of plant and soil analysis in assessing the fertiliser requirements of the oil palm in Malaya. pp. 188-193. In *Proceedings of 2nd Malaysian Soil Conf.* Ministry of Agriculture, Kuala Lumpur.
- OCHS, R. 1965. Contribution a l'etude de la fumure potassique du palmier a huile. *Oleagineux*. 20: 365-368.
- OLLAGNIER, M. 1973. Anionic nutrition of the Oil palm - Application to the fertiliser policy in North Sumatra. pp. 227-238. In *Advances in Oil Palm Cultivation*. eds. R. L. Wastie and D. A. Earp. Incorporated Society of planters, Kuala Lumpur.
- OLLAGNIER, M. and OCHS, R. 1971. Chlorine a new essential element in oil palm nutrition. *Oleagineux*. 26: 1-15.
- *OLLAGNIER, M., OCHS, R. and DANIEL, C. 1976. Alimentation on chlore du palmier a huile et du cocotier. Application a la fertilisation. *Document IRHO*. pp. 62.
- OLLAGNIER, M., OCHS, R., and MARTIN, G. 1970. Manuring of Oil palms in the World. *Fertilite*. 36: 3-63.
- PREVOT, P. and OLLAGNIER, M. 1954. Peanut and oil palm foliar diagnosis. Interrelations of N, P, K, Ca and Mg. *Pl. Physiol.* 29: 26-34.
- PREVOT, P. and OLLAGNIER, M. 1959. Law of minimum and balanced mineral nutrition. pp. 257-277. In *Plant Analysis and Fertiliser Problems*. American Inst. Biol. Sci., Washington.
- ROSENQUIST, E. A. 1962. Fertiliser Experiments on oil palms in Malaya. Part I. Yield data. *J. W. Afr. Inst. Oil Palm Res.* 3: 291-301.
- SPARNAAIJ, L. D. 1960. The analysis of bunch production in the oil palm. *J. W. Afr. Inst. Oil Palm Res.* 3: 109-180.
- TAN, K. S. 1973. Fertiliser trials on oil palms in inland soils in Dunlop Estates. pp. 248-279. In *Advances in Oil Palm Cultivation*. eds. R. L. Wastie and D. A. Earp. Incorporated Society of Planters, Kuala Lumpur.

- TAN, K. S. 1976. Efficient fertiliser usage for oil palm in inland soils. pp.262-288. In *International Developments in Oil Palm*. eds. D. A. Earp and W. Newall. Incorporated Society of Planters, Kuala Lumpur.
- TINKER, P.B.H. and SMILDE, K. W. 1963. Cation relationship and Magnesium deficiency in the oil palm. *J. W. Afr. Inst. Oil palm Res.* 4: 82-100.
- UMAR AKBAR, F. H., TAMPUBOLON, D., AMIRUDDIN and OLLAGNIER, M. 1976. Fertiliser experimentation on oil palm in North Sumatra. pp. 342-360. In *International Developments in Oil palm*. eds. D. A. Earp and W. Newall. Incorporated Society of Planters, Kuala Lumpur.
- VAN DER VOSSEN, H. A. M. 1970. Nutrient status and fertiliser responses of oil palms on different soils in the forest zone of Ghana. *Ghana J. Agric. Sci.* 3: 109-129.
- *VANDERWEYEN, R. 1952. *Notions de culture del' Elicis au Congo belge*. Brussels. pp. 239-247.
- WARRIAR, S. M. and PIGGOT, C. J. 1973. Rehabilitation of oil palms by corrective manuring based on leaf analysis. pp. 289-305. In *Advances in Oil Palm Cultivation*. eds. R. L. Wastie and D. A. Earp. Incorporated Society of Planters, Kuala Lumpur.
- WERKHOVEN, J. 1965. *La fumure du palmier a huile*. Verlags gesellschaft fur ackerbau mbh, Hanover.

* Originals not seen.