UNIVERSITI PUTRA MALAYSIA

RESPONSE OF IRRIGATED OIL PALM IN THE NURSERY AND THE FIELD TO NITROGEN, PHOSPHORUS AND POTASSIUM FERTILIZERS

IZWANIZAM BIN ARIFIN

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By

IZWANIZAM BIN ARIFIN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

August 2018

DEDICATION

In the name of Allah the most graceful and the most merciful

This thesis is dedicated to:

My beloved parents
Hj Arifin Ali & Hjh Rohani Che Mat
Hj Amsari Jafri & Hjh Jatiah Abd Samad

My lovely wife and kids

Umi Kalsom Amsari

Nurkasih Batrissyia

Amru Khalish

Supervisory committee and staffs of Institute of Tropical Agriculture and Faculty of Agriculture Universiti Putra Malaysia (UPM).

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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August 2018

Chairman : Professor Mohamed Hanafi Musa, PhD
Faculty : Agriculture

Nutrient demand for oil palm is determined by the potential yield, which is varies according to genotype, soil, palm age and environment factor. Moisture stress having a strong influence on oil palm growth and development. Irrigation project was carried out to study the growth performance and yield response of oil palm to irrigation. Therefore, this study highlight the results the major plants nutrients requirements for an oil palm and the strategies to optimize the usage of fertilizer in oil palm under irrigation system. An experiment was laid out at the Oil Palm Nursery, Felda Agricultural Services Tun Razak, Jerantut, Pahang, Malaysia (3° 52' 55" N, 102° 43' 41" E) and FASSB Tembangau 9 Estate (03°00'59.5"N, Longitude 102°28'48.5"E). Experiment of 3^3 NPK factorial fertilizer trials were conducted for oil palm seedlings in nursery and mature D × P palms planted in the year 2000 under irrigation condition. The trial was conducted on Gong chenak series (*Aquic kandiudults)* (Soil Survey Staff, 2010). The following rates were used: 0, 112 and 224 g per seedling per year for N (Ammonium sulphate); 0, 71 and 142 g per seedling per year for P (Christmas island rock phosphate); and 0, 34 and 68 g per seedling per year for K (Muriate of potash). The N and K rates tested for mature oil palm were at 0, 4 and 8 kg per palm per year, while P rate tested at 0, 2 and 4 kg per palm per year. Field operation and maintenance of trial plot was as per normal estate practices. Experiment on the NPK factorial trial on oil palm seedling showed that there is important aspect of the need for applying the adequate rate of N fertilizer rather than P and K fertilizer in order to optimize the nutrient uptake. In the absence of N fertilizer, N foliar nutrient status (1.78%), girth size (5.1 cm), seedling height (51.4 cm) and frond length (36.6 cm) was significantly the lowest. The best combination rate of fertilizer for optimum seedling growth was N1P1K1 (112 g SOA, 71 g CIPR and 34 g MOP). Results over 7 years on mature palm showed that the palms treated with complete NPK fertilizer (N1P1K1 and N2P2K2) able to produce average FFB yield at 26.50 – 26.69 t/ha, and much higher by 3.60 – 3.80 t/ha (15-17%) as compared to the plot without fertilizer (N0P0K0) at 22.90 t/ha. However, the treatments plot with the lowest yields were N0P2K0, & N0P0K1 at 21.10 t/ha & 21.12 t/ha, respectively. The study also indicated that palm growth and foliar nutrient status showed a significant response to N

manuring were recorded throughout the period of the treatment. Unlike N, no significant responses to P and K fertilizer were recorded. Fertilizer rate at N1P1K1 is the best rate to maintain optimum palm growth (particularly estimated LAI and dry frond weight), yield response and foliar nutrient status.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

RESPON KELAPA SAWIT DI KAWASAN PENGAIRAN PADA POKOK SEMAIAN DAN SAWIT MATANG TERHADAP BAJA NITROGEN, FOSFORUS DAN POTASSIUM

Oleh

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Keperluan nutrien bagi kelapa sawit ditentukan oleh potensi hasil yang mana faktor-faktor seperti genotip, tanah, umur sawit dan alam sekitar memainkan peranan yang penting. Tegasan kelembapan memberi impak yang besar terhadap pertumbuhan dan pengeluaran hasil sawit. Pelaksanaan projek pengairan bertujuan mengkaji prestasi pertumbuhan dan pencapaian hasil sawit terhadap pengairan. Oleh yang demikian, kertas kerja ini menunjukkan keputusan kajian keperluan nutrien utama bagi kelapa sawit (N, P dan K) dan strategi untuk mengoptimumkan penggunaan baja terhadap pokok kelapa sawit dengan adanya sistem pengairan. Percubaan telah dilaksanakan di tapak semaian kelapa sawit FASSB Tun Razak, Jerantut, Pahang, Malaysia (3^o 52′ 55″ N, 102^o 43′ 41″ E) dan ladang FASSB Tembangau 9 (03^o 00′ 59.5″ N, 102^o 28′ 48.5″ E). Percubaan baja 3^3 NPK faktorial telah dijalankan terhadap anak pokok kelapa sawit dan sawit matang D x P yang ditanam pada tahun 2000 di bawah pengaruh sistem pengairan. Percubaan ditapak semaian menggunakan tanah siri Gong chenak (*Aquic kandiudults)* (Soil Survey Staff, 2010). dan kadar N (Ammonium sulphate) yang diuji ialah 0, 112 dan 224 g/pokok/tahun. manakala bagi P (Christmas island rock phosphate), kadar yang diuji ialah 0, 71 dan 142 g/pokok/tahun dan kadar K (Muriate of potash) pula ialah 0, 34 dan 68 g/pokok/tahun. Kadar N dan K yang diuji ke atas sawit matang ialah pada 0, 4 dan 8 kg/pokok/tahun. Manakala nutrien P yang diuji ialah pada kadar 0, 2 dan 4 kg/pokok/tahun. Operasi dan penyelenggaraan ladang di kawasan plot percubaan adalah sebagaimana yang diamalkan oleh pengurusan ladang. Eksperimen terhadap percubaan NPK faktorial terhadap benih kelapa sawit menunjukkan bahawa kadar baja N yang mencukupi memainkan peranan penting terhadap pertumbuhan anak pokok berbanding baja P dan K. Rawatan yang tidak menggunakan baja nitrogen menunjukkan status nutrien foliar (1.78 %), saiz lilitan (5.1 cm), ketinggian anak pokok (51.4 cm) dan panjang pelepah (36.6 cm) yang paling rendah. Kombinasi baja NPK yang terbaik untuk memastikan pertumbuhan biji benih yang optimum ialah N1P1K1 (112 g SOA, 71 g CIPR dan 34 g MOP). Keputusan yang didapati daripada percubaan sawit matang

menunjukkan bahawa pokok yang dirawat menggunakan baja NPK yang lengkap (N1P1K1 dan N2P2K2) mampu menghasilkan purata hasil FFB pada 26.50 – 26.69 t/ha dan jauh lebih tinggi sebanyak 3.60 – 3.80 t/ha (15-17 %) berbanding hasil FFB pada plot yang tiada baja (N0P0K0) dengan hasil FFB sebanyak 22.90 t/ha. Walau bagaimanapun, plot rawatan dengan hasil paling terrendah adalah plot N0P2K0 dan N0P0K1 masing-masing pada kadar 21.10 t.ha dan 21.12 t/ha. Kajian ini juga menunjukkan bahwa pertumbuhan vegetatif sawit dan status nutrien daun menunjukkan tindak balas yang signifikan terhadap pembajaan N yang dicatatkan sepanjang tempoh percubaan. Secara kontra, penaburan baja fosforus (P) dan kalium (K) tidak menunjukkan tindak balas yang signifikan terhadap parameter yang direkodkan. Rawatan NPK baja pada kadar N1P1K1 menunjukkan keputusan yang terbaik untuk mengekalkan pertumbuhan vegetatift yang optimum (anggaran luas permukaan pelepah dan berat kering pelepah), hasil FFB dan status nutrien daun .

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date: 13 February 2020

Declaration by graduate student

I hereby confirm that:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
B	Boron
Ca	Calcium
Cl	Chloride
cmol	centimole
Cu	Copper
D×P	*Dura* × *pisifera*
D×T	*Dura* × *tenera*
FASSB	Felda Agricultural Services Sdn. Bhd.
Fe	Iron
FELDA	Federal Land Development Authority
FFB	Fresh fruit bunches
GAP	Good agronomic practices
ha	Hectare
K	Potassium
kg/palm	kg per palm
Kies	Kieserite
Mg	Magnesium
mm	Millimetremmmi millimetre
mm/day	millimeter per day
MOP	Muriate of potash
N	Nitrogen
NIFOR	Nigerian Institute for Oil Palm Research

O/B	Oil to bunch ratio
p	Probability
P	Phosphorous
Palms/ha	palms per hectare
PCS	Petiole cross section
PET	Potential evapotranspiration
PPPTR	Pusat Perkhidmatan Pertanian Tun Razak
PR	Phosphate rock
RCBD	Randomized complete block design
SAS	Statistical Analysis Software
SC3	Standard control 3
t	ton
t/ha/yr	ton per hectare per year

CHAPTER 1

INTRODUCTION

Malaysia currently accounts for 39% of world palm oil production and 44% of world exports. If taken into account of other oils & fats produced in the country, Malaysia accounts for 12% and 27% of the world's total production and exports of oils and fats. Today, 5.74 million hectares of land in Malaysia is under oil palm cultivation; producing 17.73 million tonnes of palm oil (CPO) and 2.13 tonnes of palm kernel oil (PKO). The largest oil palm areas were in Sarawak and Sabah with 3.06 million hectares (53%) and 2.68 million hectares (47%) in Peninsular Malaysia (MPOB, 2016). The oil palm is a perennial plant which, under suitable climatic conditions, palm growth well and high fresh fruit bunch (FFB) yield. Oil palm yield potential is reduced when trees are exposed to stressful conditions. Low moisture is the most common stressful condition oil palm faces. If oil palm trees are subjected to moisture stress during fruit development, a higher proportion of the flowers become male flowers, which do not became fruit. However, to support its growth and yield, it requires a lot of water at 5-7 mm/day (Foong, 1995) and large amounts of nutrients such as nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg). The quantities of nutrients applied vary according to palm age, expected yield, soil type, and local precipitation. In recent years, there has been increased emphasis on site-specific nutrient management to improve its growth and productivity to match its potential to the site (Chew *et al.*, 1992; Kee *et al.*, 1994). Understanding the factors that contribute to efficient fertilizer use is crucial to maximize yields and enhance economic returns (Goh and Hardter, 2003). Many trials have been conducted on a wide range of soil types, climate, and tree ages. Although, many palm nutrition studies, particularly NPK trials on inland and coastal soils are well documented (Viets, 1965; Ollagnier and Ochs, 1973; Chew and Khoo, 1977 and Kee and Chew, 1991). However, the determination of fertilizer input levels under irrigation condition and current water management practices in oil palm plantations, are almost not well documented. Furthermore, water management practices by using irrigation system widely practiced by all planters or farmers. These studies led to a recommendation for optimum nutrient management in oil palm plantations under irrigation condition and to determine input levels of fertilizers to achieve an economically optimum production.

The general objective was to evaluate the response of various fertilizer rates in relation to with irrigation condition. This study will enable us to verify the quantum effect of moisture to crop performance in a drier environment. With the nutrients identified, a specific fertilizer management can be applied to establish a causal relationship between water and nutrient management aspect on the oil palm area. Once clearly identified, this information can be used to design management system or strategies that support the nutritional requirement of the oil palm while exploiting their genetic potential for high FFB yield.

REFERENCES

Aya, F. O. and Ojuederie, B. M. (1976). The effect of supplementary irrigation and fertilizer mixture on the growth and bunch yields of the Oil Palm. In: *Int. Dev. In Oil Palm*, 1976. 389-400.

Azmi, M., Foong S.F. and Ismail, H. (2000). Effect of substituting ammonium sulphate with urea and ammonium sulphate-urea-MOP mixtures on oil palm yield. *Kemajuan Penyelidikan* Bil 35, Julai 2000. 31-38.

Broekmans, A. F. M. (1957). Growth, flowering and yield of oil palm in Nigeria. *J. W Agric. Inst. Oil Palm Res.*, 2: 187-220.

Broughton, W.J. (1977). Effects of various covers on the performances of *Elaeis guineensis* (Jacg) on different soil. *Proceedings* Int. Dev. In oil palm. Incorporated Society of Planters, Kuala Lumpur. p. 501-525.

Chan, K. W. (1979). Irrigation of oil palm in Malaysia. Proc. of the Symp. Water in Malaysia Agric. (Pushparajah, E ed.). Malaysian Society of Soil Science, Kuala Lumpur. p. 103-116.

Chan, K.W. (1981). Nitrogen requirement of oil palm in Malaysia: Fifty years of experiments conducted by Guthrie. In *The Oil Palm in Agriculture in the Eighties*. Volume II (E. Pushparajah & Sharifuddin, H. A. Hamid, eds). Incorporated Society of Planters, Kuala Lumpur. 119-153.

Chan, K.W. (1982a). Potassium requirement of oil palm in Malaysia: Fifty years of experimental results. In *Phosphorus and Potassium in the Tropics* (E. Pushparajah & Sharifuddin, H. A. Hamid, eds). Malaysian Society of Soil Science, Kuala Lumpur. 323-348.

Chan, K.S.; Chew, P.S. (1984). Volatilisation losses of urea on various soils under oil palm, in: Fertilisers in Malaysian Agriculture. Proceedings. Malasyan Society of Soil Science and Universiti Pertanian Malaysia, Kuala Lumpur, p. 91-104

Chan, K.W., Lim, K.C. and Ahmad, A. (1993). Fertiliser efficiency studies in Malaysia. In: Basiron, Y. *et al* (eds). *1991 PORIM Int. Palm Oil Conference - Agriculture*. PORIM, Kuala Lumpur: 302-311.

Chew, P S; Kee, K K; Goh, K J; Quah, Y T and Tey, S H (1992). Fertilizer management in oil palm. *Proc. of the International Conference on Fertilizer Usage in the Tropic* (Aziz, B ed.). Malaysian Society of Soil Science, Kuala Lumpur. p. 43-67.

Chew, P. S. and Khoo, K. T. (1977). Nutrient responses of perennial tree crops on a coastal clay soil in Peninsular Malaysia. In: *Proc. Con. on Classification and Management of Tropical Soil* (K. T. Joseph, ed). 446-454.

Corley, R. H. V. and Hong, T. K. (1982). Irrigation of oil palms in Malaysia. In: *Oil Palm in Agriculture in the Eighties* (Pushparajah E. and P. S. Chew eds) Inc. Soc. of Planters. 1: 327-342.

Foong, S.F. (1993) Potential evapotranspiration, potential yield and leaching losses of oil palm. In: Basiron, Y. et al., (eds). 1991 PORIM Int. Palm Oil Conf. - Agriculture, PORIM, Kuala Lumpur. pp 105-119.

Foong, S. F. (1995). Pencapaian kearah hasil potensi sawit. *Kemajuan Penyelidikan* Bil 25, Julai 1995. 3-15.

Foong, S. F. (1999). Impact of moisture on potential evapotranspiration, growth and yield of oil palm. In: *Proceedings of 'the* 1999 *PORIM International Palm Oil Congress (Agriculture),* Kuala Lumpur.

Foong, S.F. and Syed Sofi, S.O. (1987). Two 4x2 NK factorial trials on Rengam and Kuantan series soils in mature oil palm. In *Proceedings of 1987 International Oil Palm/Palm Oil Conference – Agriculture.* (Halim et al., eds), Palm Oil Research Institute of Malaysia, Kuala Lumpur. 329-335.

Foster, H.C. and Chang, K.C. 1977. Seasonal fluctuations in oil palm leaf nutrient levels. MARDI Research Bulletin. 5: 74-90. Malaysian Agricultural Research and Development Institute, Kuala Lumpur, Malaysia.

Foster, H.L.; Chang, K.C.; Tayeb, D.M. and Zin, Z.Z. (1985). Oil palm yield responses to N and K fertilizer in different environments in Peninsular Malaysia. PORIM Occasional Paper. pp 16-23.

Foster, H.L.; Tarmizi, M.A.; Chang, K.C.; Zin, Z.Z. and Halim, H.A. (1986). Fertilizer recommendations for oil palm in Peninsular Malaysia. PORIM Technology 13: 125.

Foster, H.L.; Tayeb, D.M. and Gurmit, S. (1988). The effect of fertilizers on oil palm bunch components in Peninsular Malaysia. In: Halim, P.A.K. et al., (eds). Proc. 1987 Int. Oil Palm Conf., PORIM and ISP, Kuala Lumpur. pp 294-304.

Foster, H.L. (2003). Assessment of oil palm fertilizer requirements. In: Oil Palm: Management For Large And Sustainable Yields (Fairhurst, T. and Hardter, R., eds.). Potash and Phosphate Institute (PPI), Potash and Phosphate Institute Canada (PPIC) and Int. Potash Inst. (IPI), Singapore: 231-257.

Goh, K.J. and Chew, P.S. (1995). Direct application of phosphate rocks to plantation tree crops in Malaysia. In: Dahanayake, K., van Kauwenbergh, J. and Hellums, D.T. (eds.) Direct Application of Phosphate Rock and Appropriate Technology Fertilizers in Asia - What Hinders Acceptance and Growth. Institute of Fundamental Studies & IFDC, Kandy, pp. 59-76.

Goh, K.J.; Gan, H.H. and Soh, A.C. (2002). Oil palm productivity: Commercial FFB yield analysis. In: MPOA seminar 2002: R&D for competitive edge in the Malaysian OP industry, Malaysian Palm Oil Association, Kuala Lumpur: Preprint.

Goh, K. J., and Hardter, R. (2003). General oil palm nutrition. In "Oil Palm: Management for Large and Sustainable Yields" (T. Fairhurst and R. Hardter, Eds.), pp. 191–230. PPI/PPIC and IPI, Singapore.

Goh, K.J., Chew, P.S. and Kee, K.K. (1994). K nutrition for mature oil palm in Malaysia. *IPI Research Topic* No 17. Basal, Switzerland.

Goh, K.J., Chew, P.S., Heng, Y.C., Tey, S.H. and Gan, H.H., 1997. Developing decision support systems for plantations: A new role for agronomists. *The Planters, 73*, 687-693.

Gray, B.G., and Hew, C.K. (1968). Cover management on oil palm on the west coast of Malaysia. *Proceedings of Conf. On Oil Palm Dev. In Malaysia*. Incorp. Soc. Of Planters, Kuala Lumpur. p. 56-65.

Han, K.J. and Chew, P.S. (1982). Growth and nutrient content of leguminous covers in oil palm plantations. Pushparajah, E. and Chew, P.S. (eds). *The oil palm agriculture in the eighties*. Vol. II. Incorporated Society of Planters, Kuala Lumpur. 306-322.

Henson, I.E. (1999). Corporate ecophysiology of oil palms and tropical rainforest. Chapter 2. In *Oil palm and the environment*. Ed: Gurmit Singh, Lim, K.H., Teo Ley, David. MOPGC, 1999.

Kee, K K; Goh, K J; Chew, P S and Tey, S H (1994). An integrated site specific fertilizer recommendation system (INFERS) for high productivity in mature oil palm. *International Planters ConferenceonManagement for Enhanced Profitability in plantation* (Chee, K H ed.). Incorporated Society of Planters, Kuala Lumpur. p. 38-100.

Kee, K. K. and Chew, P. S. (1991). Oil palm response to nitrogen and drip irrigation in a wet monsoonal climate in Peninsular Malaysia. In: *Proc.* 1991 *PORIM Int. Palm Oil Conf*, Kuala Lumpur. 321-339.

Lim, K.C.; Yee, C.B.; Goh, K.H., Chan, K.W. (1985). Results of field experiment comparing various nitrogen fertilisers for oil palm, in Bachik A.T.; Pushparajah E. (Eds.). International Conference on Soils and Nutrition of Perennial Crops. Proceedings. Malaysian Society of Soil Science, Kuala Lumpur, pp. 393-409.

Mathew, C. (1998). The introduction and establishment of a new leguminous cover crop *Mucuna bracteata* under oil palm in Malaysia. The Planter. Incorp. Soc. Of Planters. Kuala Lumpur. 74: p 359-368.

Mathews, J.; Wong, H. K. and Chua, K.H. (2005). A review of oil palm potential yields in Sarawak soils and the commercial yield perfonnance of Sarawak Oil Palm Berbad(SOPB) In:Proceedings of the2005 National Seminar on Practices for Super High Yielding Plantation (Ariffin Darus, Tarmizi A M and Zin Zawawi Zakaria, eds.). Malaysian Palm Oil Board, Seri Kembangan, Selangor. 132-157.

MPOB (2016). http://bepi.mpob.gov.my/index.php/en/statistics/area/176-area-2016 (10 Ogos 2017).

Nazeeb, M.; Tang, M.K.; Letchumanan, A. and Loong, S.G. (1993). Trials on cessation of manuring before replanting. In: 1993 PIPOC PORIM Int. Conf. Palm Oil Congress: Update and Vision. Kuala Lumpur. pp 293-312.

Ng, S. K. and Thamboo, S. (1967). Nutrient contents of oil palms in Malaya). Nutrients required for reproduction: Fruit bunches and male inflorescences. *Malay. Agric. J.*, 46:3-45.

Ng, S. K. and Thong, K. C. (1985). Nutrient requirements for exploiting yield potentials of major plantation crop in the tropics. In: *Potassium in the Agricultural Systems of the Humid Tropics* Proc. 1 gth Colloquium, Int. Potash Inst. Bangkok, Thailand. 81-95.

Ng, S. K; Thamboo, S. and De Souza, P. (1968). Nutrient contents of oil palms in Malaya II. Nutrients in vegetative tissues. *Malay. Agric. J.*, 46: 332-391.

Ng, S.K. (1977). Review of oil palm nutrition and manuring-scope for greater economy in fertilizer usage. In *International Developments in Oil Palm* (D. A. Earp and W. Newall, eds). Malaysian Society of Soil Science, Kuala Lumpur. 209-233.

Ochs, R. and Daniel, C. (1976). Research on techniques adapted to dry region. In: *Oil Palm Research* (Corley, R. H. V; J.J. Hardon and B. J. Wood, eds) Amsterdam: Elsevier. 315-330.

Ollagnier, M. and Ochs, R. (1973). Interaction between nitrogen and potassium in the nutrition of the tropical oil palm. *Oleagineux.* 28: 11.

Paramanathan, S., 1997. The Need for Standardization of Soil Survey Methodology in Malaysia. *In:* J. Shamsuddin and J. Hamdan (Eds.), *Proc. Soil Sci. Conf. Malaysia 1997*. Mal. Soc. Soil Science, Serdang, Malaysia, 92-129.

Patrick Ng, H.C., Chew, P.S., Goh, K.J. and Kee, K.K. (1999). Nutrients requirements and sustainability in mature oil palms – an assessment. *The Planter* Vol. 75, 1999. 331-345.

Pushparajah, 1977. Nutritional Status and Fertilizer Requirements of Malaysian Soils for Hevea brasiliensis. Unpub. D.Sc Thesis, State University of Ghent, Belgium. 276 pp.

Pushparajah, E. and Chew, P.S. (1998). Integrated nutrient management for sustaining high yields of plantation tree crop in Tropical Asia. *Soil Science Conference 1998*.

Rajaratnam, J.A., Chan, K.W. and Goh, K.H. (1980). The foundation for selecting leaf 17 for nutrient requirements of mature oil palms. *In:* Joseph, K.T. (ed). Proc. Conf. on Classification and Management of Tropical Soils, 1977, MSSS, Kuala Lumpur: 340-348.

Rosman, R. and Foong, S.F. (2000). Effect of timing, compensation rate and MOP application on urea efficiency on oil palm yield. *Kemajuan Penyelidikan* Bil 35, Julai 2000. 24-29.

Shorrocks, V. M. (1965). Mineral nutrition, growth and nutrient cycle of *Hevea brasiliensis* II. Nutrient cycle and fertilizer requirements. *J. Rubber Res. Inst.*, 19: 48-61.

Soil Survey Staff (2010). Keys to Soil Taxonomy – Eleventh Edition. United States Department of Agriculture, Natural Resources Conservation Service. Washington D.C.

Strohbusch, D .F. (1968). Use and abuse of fertilisers in oil palm nurseries. Oil palm developments in Malaysia. Proceedings of the First Malaysian Oil Palm Confrence.. 50-55.

Tan, B. T. (1988) Cost of palm oil production in major producing countries. In: *Proc. of* 1987 *International Oil Palm Conference -Agriculture,* Kuala Lumpur: PORIM. 1-23.

Tan, K.S. (1976). Efficient fertilizer usage for oil palm on inland soils. In *Proc. Malaysian Int. Agric. Oil Palm Conf*. Earp, D.A. and Newall, W. (eds). Kuala Lumpur. 262-289.

Tang, M.K.; Nazeeb, M. and Loong, S.G. (1999) An insight into fertiliser types and application methods in Malaysian oil palm plantations. The Planter 75 (876): 115-137.

Tarmizi, A.M.; Foster, H.L.; Zin, Z.Z. and Chow, C.S. (1986). Statistical and economic analysis of oil palm fertilizer trials in Peninsular Malaysia between 1970- 1981. PORIM Occasional Paper 22:122 pp.

Tarmizi, A.M.; Tayeb, M.D.; Foster, H.C.; Hamdan, A.B.; Khalis, H. (1993). Relative efficiency of urea to sulphate of ammonium in oil palm: Yield response and environmental factors, in: Y Barison et al. (Eds.). 7997 PORIM International Oil Palm Conference 'Progress, Prospects and Challenges Towards the 21 st Century'. Proceedings. PORIM, Kuala Lumpur. p. 340-348.

Teo, G. B; Chew, P. S; Goh, K. J. and Kee, K. K. (1998). Optimising return from fertilizer for oil palm: An Integrated Agronomic Approach. Proposed Paper for 1998 IOPRI Conference, September 1998.

Teo, L., Ong, K.P. and Zainuriah, A. (2000). Effect of fertilizer withdrawal prior to replanting on oil palm performance. In *Proceedings of the International Planters Conference on Plantation Tree Crops in the New Millennium: The Way Ahead.* (E. Pushparajah, eds). The Incorporated Society of Planters.

Teoh, K.C. and Chew, P.S. (1984). Investigation on areas and frequencies of fertilizer application in mature oil palms. In Proc. Int. *Conf. On Soils and Nutrition of Perennial Crops.* (Bachik, A.T. and Pushparajah., eds). MSSS, Kuala Lumpur: 375-387.

Viets, F. G. (1965). The plant's need for and use of nitrogen. In: *Soil Nitrogen* Amer. Soc. of Agronomy, Wisconsin.

Von Uexkull, H. R. and Fairhurst, T. H. (1991). *Fertilizing for High Yield and Quality -The Oil Palm.* IPI Bulletin No.12, International Potash Institute, Switzerland.

Zin, Z.Z. (1995). Phosphate rock fertiliser requirements for oil palm in Peninsular Malaysia. Paper presented in Seminar on the Use of Reactive Phosphate Rock for Direct Application at Petaling Jaya, Selangor on 20 July 1995.

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