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**ASSESSMENT OF THE SPATIAL AND TEMPORAL PROLIFERATION
OF UPPER STEM ROT DISEASE IN OIL PALM PLANTATIONS
(*ELAEIS GUINEENSIS*) IN THE KUDAT REGION, SABAH.**

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**DISSERTATION SUBMITTED IN FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE
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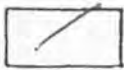
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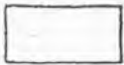
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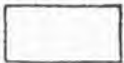
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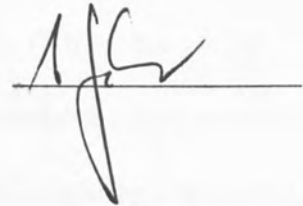


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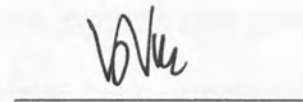


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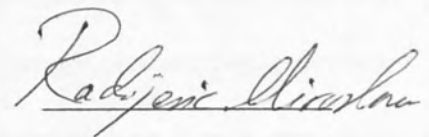
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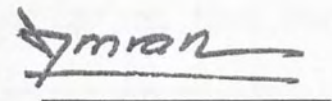
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**3. EXAMINER 2**

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**4. DEAN**

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**PENILAIAN RUANGAN DAN MASA TERHADAP PERTUMBUHAN
PENYAKIT REPUT BATANG ATAS DALAM LADANG KELAPA SAWIT
(*ELAEIS GUINEENSIS*) DI KAWASAN KUDAT, SABAH**

ABSTRAK

Kajian tersebut dijalankan untuk menilai variasi berkenaan dengan ruang dan masa demi meramal pertumbuhan penyakit reput batang atas (RBA) di kawasan Kudat, Sabah. Peringkat pertumbuhan penyakit RBA direkodkan melalui visual mengikut 10 kategori dan dilaksanakan di Blok 3S dan 4S dalam estat Langkong (N06°30'39.8", E116°42'30.5") dari tahun 1997 sehingga 2004. Data akan dianalisis melalui *postmap* (Surfer Version 7 software package) untuk menyiasat corak pertumbuhan penyakit tersebut utama dan kawasan yang paling berkemungkinan bagi penyakit RBA (Crimestat software package). Blok 3S dan 4S menduduki sebanyak 24% daripada perhubungan berkenaan dengan ruang dalam eksperimen pengawasan *semi-variogram* walaupun mereka menunjukkan perhubungan secara ruangan yang lemah. Terdapat hubungan yang rapat antara peristiwa jasad berbuah *Ganoderma* dengan peristiwa pokok kelapa sawit yang tumbang pada tahun berturut-turunan. Sebaliknya, peristiwa batang atas patah dan peristiwa pelepah patah tidak wujud hubungan malahan kedua-dua peristiwa tersebut tidak wujud hubungan dengan peristiwa jasad berbuah *Ganoderma* dengan peristiwa pokok kelapa sawit yang tumbang. Hasil daripada kajian tersebut, dapat disimpulkan bahawa jasad berbuah *Ganoderma* bukan punca yang menyebabkan penyakit RBA dalam ladang kelapa sawit di estat Langkong. Pengawasan melalui jangka masa panjang terhadap peringkat-peringkat penyakit RBA adalah amat diperlukan untuk mengatasi masalah pertumbuhan penyakit kulat *Ganoderma* berkenaan dengan masa.



ABSTRACT

This study was initiated to assess the spatial and temporal variation to predict the distribution of the Upper Stem Rot (USR) disease in Kudat region, Sabah. The USR disease status was visually recorded according to 10 stages and carried out in Block 3S and 4S within the Langkong estate (N06°30'39.8", E116°42'30.5") from 1997 until 2004. Data analyzed through employing post map (Surfer Version 7 software package) to investigate pattern of preferential distribution and hotspots of USR disease incidences (Crimestat software package). Block 3S and 4S appear a total of 24% of spatial relationship in experimental semi-variogram modelling although they represented that weak spatial dependence existed between them. There has a close relationship in Block 3S and 4S between *Ganoderma* fruiting bodies and fallen palm incidences in the following year by chronological events. On the other hand, upper stem fracture and skirting incidences did not showed any relationship, and between them with *Ganoderma* fruiting bodies and fallen palm incidences. From this present result, concluded that upper stem rot incidence was not caused by *Ganoderma* fruiting bodies. Long-term monitoring of disease stages of USR is required to resolve temporal proliferation of the *Ganoderma* disease in both blocks.



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LIST OF SYMBOLS

$^{\circ}$	Degree
h	Vector
θ	Direction
C_0	Nugget effect
C_1	Spatial dependence
C	Sill
a	Range
NR	The strength of the spatial dependence



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CHAPTER 1

INTRODUCTION

1.1 Oil Palm in Malaysia

Palm oil has become one of the main contributors to Malaysia economy as a result of the Government's Crop Diversification Programme in the 1960s (Fuad *et al.*, 1999). Malaysia is the world's largest producer of oil palm and exports almost all its production (Fuad *et al.*, 1999). The annual export revenue in 2003 amounted to RM 27.7 billion and oil palm contributed 7.3 % to the national GDP (Department of Statistics Malaysia, 2003). However, intense oil palm monoculture has resulted in an environmental imbalance causing numerous pathogenic diseases, pests and physiological disorders (Turner, 1981).

1.2 Oil Palm Stem Rot

One of the most important diseases in oil palm is currently basal stem rot (BSR) in Malaysia (Turner, 1981 and Singh, 1991). *Ganoderma boninense*, the pathogen causing basal stem rot and upper stem rot (USR) disease of oil palm remain the most significant constraint to sustainable oil palm production in South East Asia with



numerous yield losses through direct loss of the stand, reduced yield of diseases palms and requirement for earlier replanting (Flood *et al.*, 2002).

The ratio of USR to BSR in different estates ranges from 1:10 to 1:1 and in some fields the incidence of USR exceeds that of BSR (Hasan *et al.*, 2004). In some commercial field in Lonsum estates situated in Indonesia, the incidence of USR is higher than incidence of BSR (Flood *et al.*, 2002) meanwhile the incidences of USR have shown as high as 5 % in some Malaysia fields (Turner and Gillbanks, 1974). In the Kudat region of Sabah, the incidence of USR is also higher than incidence of BSR (field observation) and for 30 years old palm tree estates, 5 % of the total area must be replanted (Hoong, personal communication, Borneo Samudera Sdn. Bhd.).

1.3 Current Status

At present, control strategies are only aimed at delaying the progress of infection and prolonging the productive life of the palm (Ariffin *et al.*, 1989b; Ariffin and Idris, 1991a; Ariffin *et al.*, 2000; Flood *et al.*, 2000; George *et al.*, 1996; George *et al.*, 2000; Idris *et al.*, 2002; Idris and Ariffin, 2003; Joseph, 2000; Khairudin, 1990 and 1993; Lim *et al.*, 1993; Marshall and Hunt, 2004; Nazeeb *et al.*, 2000; Rao *et al.*, 2003; Sariah and Zakaria, 2000; Singh, 1991; Soepena *et al.*, 2000). In addition, although treatment of early stages of disease can be successful, by this time when the fruiting body of *G. boninence* appears, it is discovered that at least one-half of the stem part has been rot and cannot be treated anymore (Paulinus, personal communication, Borneo Samudera Sdn. Bhd).



The studies of Miller *et al.* (1999) using somatic incompatibility and mitochondrial DNA profiling of isolates taken from palms revealed that the considerable heterogeneity with different genotypes even occurring infected palm. Although molecular methods have been developed to detect the fungus in the palm tree, those methods are not applicable for a broad scale of field. Thus, prediction of high-risk areas within a plantation, which can be monitored and treated within the framework of precision farming, is needed immediately.

1.4 Geostatistics

Geostatistics is based on the theory of regionalized variables developed by Matheron in the late 1950 on the basis of empirical relations, which Krige (1950), D.G., a South African geologist, applied for predicting the gold reserves in placers (Armstrong, 1998). Geostatistics focuses on the analysis of spatially distributed variables and the prediction or estimation of values at unsampled locations.

Nelson *et al.* (1999) stated that regional surface maps are appropriate when a variable (pathogen propagule density, disease incidence, insect vector abundance, etc) exhibits positive spatial autocorrelation beyond the boundary of a single field. Nowadays, it has been used in plant pathology to analyze the spatial distribution of plant disease epidemics, mainly at plot or field scales (Kocks *et al.*, 1998; Van de Lande and Zadoks, 1999; Castrignanò *et al.*, 2000; Pethybridge and Madden, 2003; Xu and Madden, 2004).



1.5 Aims of this Study

This study was initiated to assess the spatial and temporal variation in order to predict the distribution and proliferation of the disease.

To achieve the above objective following tasks were carried out:

1. Variography of the spatial distribution of USR disease.
2. Analysis of the temporal proliferation of USR disease within eight years.



CHAPTER 2

LITERATURE REVIEW

This chapter was divided into two main parts that upper stem rot disease in oil palm and spatial variability analyses.

2.1 Upper Stem Rot disease in Oil Palm

Upper stem rot is commonly found on diseased palms symptoms similar to spear rot, bud rot, bunch rot and basal stem rot caused by root diseases (Ng, 1972). Lower leaves first become yellow and die from the tip to the base. This condition progresses to the middle of the crown and finally affected the spear leaves. The stem tissues will show a brown rot while the roots of the palm are not affected.

Infection of oil palm by *Fomes noxius* (also known as “*Phellinus noxius*”) to produce symptoms of USR disease has been known in Peninsular Malaysia and Sabah, Indonesia and West Africa (Turner, 1969). Usually, USR affected palms died. Both of fungus (*Fomes noxius* and *Ganoderma boninense*) are also responsible for death to a majority of young palms planted in areas where a former rubber stand was heavily infected with brown root disease (Turner, 1981).



The disease is expected to spread from infected debris (through root contact or mycelial spread) would produce a homogenous pathogen population in the infected oil palm as can be seen with other wood rotting fungi – *Heterobasidion annosum* (Stenlid, 1985 cited in Hasan and Flood, 2003) or *Phellinus noxius* (Hattori *et al.*, 1996 cited in Hasan and Flood, 2003) where one clone of the pathogen can extend over several metres.

2.1.1 Causal agent

Reported earlier by Turner (1981) stated that *Fomes noxius* is the primary causal factor of upper stem rot disease. He also stated that fructification of *F. noxius* only develops on frond butts of palms which are affected by an extensive stem rot. However, *F. noxius* was not isolated from these rotten stem tissue samples. Turner (1969) showed that sporophores of *Ganoderma* spp. are also found on lesions, but it is believed that these are formed as the result of secondary colonisation of tissues destroyed primarily by *F. noxius*. Thompson (1931) cited in Flood *et al.* (2002) also suggested that *Ganoderma* spores which are responsible for USR disease are usually associated with *F. noxius* species but due to inability of researchers to artificially inoculate with *Ganoderma* in these diseased palms; hence this theory lost vogue.

A total of 75 isolates of *Ganoderma* were collecting from 21 locations in Peninsular Malaysia and one in Sabah (Turner, 1981). Based on *in vitro*, morphological studies, *G. boninense* and *G. zonatum* were associated with the rotten upper stem. Flood *et al.* (2002) stated that USR are always causing discrete lesions



originate from the axils of the frond base and spread in successive wave of rot, each delimited by the brown or black line of *Ganoderma* infections.

Ariffin *et al.* (1989a) revealed that the black line observed in the stem of oil palm infected with *G. boninense* is caused by a single mycelium and thus emphasizes the fungal origin of its formation. As presence of fungal hyphae almost exclusively on one side of the black line precludes the possibility of a dual infection involving another fungus and clearly indicates that *G. boninense* is the sole fungus present.

Another study on the effects of injured and non-injured roots of oil palm on the infection by *G. boninense* was carried out by Malaysian Palm Oil Board (MPOB) in 2001. This study indicated that heavily injured roots influenced the speed of *G. boninense* infection in oil palm. The rate of the speed of *G. boninense* infection was between 1.62 to 2.12 cm month⁻¹, with the average being 1.83 cm month⁻¹ (MPOB, 2001).

a. *Ganoderma boninense*

The fungus belongs to the true fungi phylum, Eumycophyta (known as Basidiomycota); derived from Basidiomycetes class, with the subclass being Holobasidiomycetidae. The order and family of *G. boninense* is Aphyllophorales (known as Polyporales) and Ganodermataceae respectively (Svrček, 1983). The larger basidiomycetes which bear basidiospores are the familiar encrustations, brackets, toadstools and similar fructifications found on decaying timber are fruiting bodies



REFERENCES

- Akbar, U., Kusnadi, M. and Ollagnier, M., 1971. Influence of the type of planting material and mineral nutrition on oil palm stem rot due to *Ganoderma*. *Oléagineux*, 26^e année, n^o 8-9: 527-534.
- Ariffin, D. and Idris, A.S., 1991a. Investigation on the control of *Ganoderma* with dazomet. In: Yusof, B. et al (eds) *Proceedings of the 1991 PORIM International Palm Oil Conference- Progress, Prospects and Challenges Towards the 21st Century*, 424-429.
- Ariffin, D. and Idris, A.S., 1992. The *Ganoderma* selective medium (GSM). *Malaysia Palm Oil Board T.T.* 8.
- Ariffin, D., Idris, A.S. and Abdul, H.H., 1989a. Significance of the black line within oil palm tissue decayed by *Ganoderma boninense*. *Elaeis* 1(1), 11-16.
- Ariffin, D., Idris, A.S. and Abdul, H.H., 1991b. Histopathological studies on colonization of oil palm root by *Ganoderma boninense*. *Elaeis* 3(1), 289-293.
- Ariffin, D., Idris, A.S. and Azahari, 1996. Spread of *Ganoderma boninense* and vegetative compatibility studies of a single field palm isolates. In: Darus, et al. (eds) *Proceedings of the 1996 PORIM International Palm Oil Congress (Agriculture Conference)- Competitiveness for the 21st Century*, 317-329.
- Ariffin, D., Idris, A.S. and Singh, G., 2000. Status of *Ganoderma* in oil palm. In: Flood, J., Bridge, P.D. and Holderness, P. (eds). *Ganoderma Disease of Perennial Crops*, 49-68.
- Ariffin, D. and Idris, A.S., 2002. Progress and research on *Ganoderma* basal stem rot of oil palm. In: *Recent Progress in the Management of Peat and Ganoderma*, 6-7 May 2002, 50.



- Ariffin, D., Singh, G. and Lim, T.K., 1989b. *Ganoderma* in Malaysia- current status and research strategy. In: Jalani *et al.* (eds) *Proceedings of the 1989 PORIM International Palm Oil Development Conference-Module II: Agricultural*, 5-9 September 1989, 249-297.
- Ariffin, D. and Wahid, M.B., 2000. Intensive IPM for management of oil palm pests. *MPOB Bulletin Oil Palm* **41**: 1-14.
- Armstrong, M., 1998. *Basic Linear Geostatistics*. Springer, Germany.
- Barnes, R., 2002. *Variogram Tutorial*. Golden Software Institute.
- Byrne, D.N., Rathman, R.J., Orum, T.V. and Palumbo, J.C., 1996. Localized migration and dispersal by the sweet potato whitefly, *Bemisia tabaci*. *Oecologia* **105**: 320-328.
- Castrignanò, A., Goovaerts, P., Lulli, L. and Bragato, G., 2000. A geostatistical approach to estimate probability of occurrence of *Tuber melanosporum* in relation to some soil properties. *Geoderma* **98**: 95-113.
- Craig, R.L. and Levetin, E., 2000. Multi-year study of *Ganoderma* aerobiology. *Aerobiologia* **16**: 75-81.
- Davis, J.C., 2002. *Statistics and Data Analysis in Geology*. 3th ed. John Wiley and Sons, U.S.A.
- Department of Statistics Malaysia, 2003. *Monthly External Trade Statistics December 2003*. Kuala Lumpur.
- Deverall, B.J., 1981. *Fungal Parasitism*. 2nd ed. Edward Arnold, U.K.
- Faridah, A., 2000. Spatial and sequential mapping of the incidence of BSR of oil palms (*Elaeis guineensis*) on a former coconut (*Cocos nucifera*) plantations. In:



- Flood, J., Bridge, P.D. and Holderness, M (eds). *Ganoderma Disease of Perennial Crops*. CABI, 183-194.
- Faud, M.A., Rohana, A.R. and Chua, B.G., 1999. Socio-economic considerations in the development of jungle to oil palm. In: Gurmit Singh *et al.* (eds). *Oil Palm and the Environment A Malaysian Perspective*. Malaysian Oil Palm Growers' Council, 1-8.
- Flood, J., Hasan, Y. and Foster, H., 2002. *Ganoderma* diseases of oil palm- an interpretation from Bah Lias Research Station. *The Planter* **78(921)**: 689-710.
- Flood, J., Hasan, Y., Turner, P.D. and O'Grady, E.B., 2000. The spread of *Ganoderma* from infective sources in the field and its implications for management of the disease in oil palm. In: Flood, J., Bridge, P.D. and Holderness, M (eds). *Ganoderma Disease of Perennial Crops*. CABI, 101-112.
- Gassner, A., Faisal, M.N. and Schnug, E., 2003. Geostatistics for agricultural management. In: Ahmad, A., Musta, B., Mun, H.C., Wan, V.L., Yan, P.M. and Zulkifil, Z (eds). *Proceedings of the Seminar on Science and Technology 2003*. University Malaysia Sabah, 269-280.
- Gassner, A. and Schnug, E., 2004. Geostatistics for soil science. In: Lal *et al.* (eds). *Encyclopedia of Soil Science*, in press.
- George, S.T., Chung, G.F. and Zakaria, K., 1996. Updated results (1990-1995) on trunk injection of fungicides for the control of *Ganoderma* basal stem rot. In: Ariffin *et al.* (eds) *Proceedings of the 1996 PORIM International Palm Oil Congress (Agriculture Conference)- Competitiveness for the 21st Century*, 508-515.
- George, S.T., Chung, G.F. and Zakaria, K., 2000. Benefits of soil mounding tall palms in a high *Ganoderma* incidence area in Lower Perak. In: Pushparajah, E. (eds)



Proceedings of the International Planters Conference on Plantation Tree Crops in the New Millennium: the Way Ahead, 17-20 May 2000, 565-575.

Goovaerts, P., 1997. *Geostatistics for Natural Resources Evaluation*. Oxford, U.K.

Hasan, Y. and Flood, J., 2003. Colonisation of rubber wood and oil palm blocks by monokaryons and dikaryons of *Ganoderma boninense*- implications to infection in the field. *The Planter* **79(922)**: 31-38.

Hasan, Y., Foster, H.L. and Flood, J., 2004. Investigations on the causes of upper stem rot (USR) on standing mature oil palms. *Mycopathologia*, in review.

Hashim, K., 1990. *Basal Stem Rot of Oil Palm: Incidence, etiology and Control*. M. Agri. Sci. Thesis, Universiti Putra Malaysia, Malaysia.

Ho, Y.W. and Nawawi, A., 1985. *Ganoderma boninense* pat. from basal stem rot of oil palm (*Elaeis guineensis*) in Peninsular Malaysia. *Pertanika* **8**: 425-428.

Ho, Y.W. and Nawawi, A., 1986a. Isolation, growth and sporophore development of *Ganoderma boninense* from oil palm in Malaysia. *Pertanika* **9(1)**: 69-73.

Ho, Y.W. and Nawawi, A., 1986b. Diurnal periodicity of spore discharge in *Ganoderma boninense* pat. from oil palm in Malaysia. *Pertanika* **9(2)**: 147-150.

Houlding, S.W., 1994. *3D Geoscience Modeling: Computer Techniques for Geological Characterization*. Springer-Verlag. Hong Kong.

Idris, A.S., 1999. Basal Stem Rot (BSR) of oil palm (*Elaeis guineensis* Jacq.) in Malaysia: Factors Associated with Variation in Disease Severity. Ph.D thesis, Wye College, University of London, U.K.



- Idris, A.S. and Ariffin, D., 2003. *Ganoderma* penyakit reput pangkal batang dan kawalannya. *Risalah Sawit* **11**: 1-12.
- Idris, A.S., Ismail, S. and Ariffin, D., 2004. Innovative technique of sanitation for controlling *Ganoderma* at replanting. *Malaysia Palm Oil Board T.T.* **213(220)**.
- Idris, A.S., Ariffin, D., Swinburne, T.R. and Watt, T.A., 2000. The identity of *Ganoderma* species responsible for BSR disease of oil palm in Malaysia-pathogenicity test. *Malaysia Palm Oil Board T.T.* **103(77b)**.
- Idris, A.S., Ismail, S., Ariffin, D. and Ahmad, H., 2002. Control of *Ganoderma*-infected palm-development of pressure injection and field applications. *Malaysia Palm Oil Board T.T.* **148(131)**.
- Idris, A.S., Yamaoka, M., Hayakawa, S., Basri, M.W., Noorhasimah, I. and Ariffin, D., 2003. PCR technique for detection of *Ganoderma*. *Malaysia Palm Oil Board T.T.* **202(188)**.
- Joseph, H., 2000. *Variations in trichoderma frm oil palm rhizosphere and its biological activities against Ganoderma boninense*. Dissertation Bachelor Science. University Putra Malaysia (unpublished).
- Jourdan, C. and Rey, H., 1997. Architecture and development of the oil-palm (*Elaeis guineensis* Jacq.) root system. *Plant and Soil* **189**: 33-48.
- Journel, A.G., 1983. Nonparametric estimation of spatial distributions. *Mathematical Geology* **15(3)**: 445-468.
- Khairudin, H., 1990. *Basal stem rot of oil palm: incidence, etiology and control*. Dissertation Bachelor Science. University Putra Malaysia (unpublished).



- Khairudin, H., 1993. Basal stem rot of oil palm caused by *Ganoderma boninense*: an update. In: *Proceedings of the 1993 PORIM International Palm Oil Congress 'Update and Vision'-Agriculture 20-25 September 1993*, 739-748.
- Kocks, C.G., Zadoks, J.C. and Ruissen, T.A., 1998. Response of black rot in cabbage to spatial distribution of inoculum. *European Journal of Plant Pathology* **104**: 713-723.
- Kuzyakova, I.F., Romanenkov, V.A. and Kuzyakov, Y.V., 2001. Geostatistics in soil Agrochemical studies. *Eurasian Soil Science* **34(9)**: 1011-1017.
- Latiffah, Z., Harikrishna, K., Tan, S.G., Abdullah, F. and Ho, Y.W., 2002. Restriction analysis and sequencing of the ITS regions and 5.8S gene of rDNA of *Ganoderma* isolates from infected oil palm and coconut stumps in Malaysia. *Annals of Applied Biology* **141(2)**: 133-142.
- Levine, N., 2002. CrimeStat II: A Spatial Statistics Program for the Analysis of Crime Incident Locations (ver. 2.0). Ned Levine and Associates: Houston, TX/
National Institut of Justice, Washington, DC.
<http://www.icpsr.umich.edu/NACJD/crimestat.html>.
- Lim, K.H., Chuah, J.H. and Ho, C.Y., 1993. Effects of soil heaping on *Ganoderma* infected oil palms. In: *Proceedings of the 1993 PORIM International Palm Oil Congress 'Update and Vision'-Agriculture 20-25 September 1993*, 477-485.
- Marshall, R. and Hunt, R., 2004. Low cost control for basal stem rot- a Poliamba initiative. *The Planter* **80(936)**: 173-176.
- Miller, N.G., Holderness, M. and Bridge, P.D., 2000. Molecular and morphological characterization of *Ganoderma* in oil-palm plantings. In: Flood, J., Bridge, P.D. and Holderness, P. (eds). *Ganoderma Disease of Perennial Crops*, 159-182.



- Miller, N.G., Holderness, M., Bridge, P.D., Chung, G.F. and Zakaria, M.H., 1999. Genetic diversity of *Ganoderma* in oil palm plantings. *Plant Pathology* **48(5)**: 595-603.
- Moncalvo, J.M., 2000. Systematics of *Ganoderma*. In: Flood, J., Bridge, P.D. and Holderness, P. (eds). *Ganoderma Disease of Perennial Crops*, 23-45.
- MPOB, 2001. *MPOB Annual Research Review 2001*. Kuala Lumpur.
- Nazeeb, M., Barakabah, S.S. and Loong, S.G., 2000. Potential of high density oil palm plantings in diseased environment. *The Planter* **76(896)**: 699-710.
- Nelson, R.N. et al, 1999. Applications of geographic information systems and geostatistics in plant disease epidemiology and management. *Plant Disease* **83(4)**: 308-319.
- Ng, S.K., 1972. *The Oil Palm, Its Culture, Manuring and Utilisation*. International Potash, France.
- Pethybridge, S.J. and Madden, L.V., 2003. Analysis of spatiotemporal dynamics of virus spread in an Australian hop garden by stochastic modeling. *Plant Disease* **87(1)**: 56-62.
- Pilotti, C.A., 2005. Stem rot of oil palm caused by *Ganoderma boninense*: pathogen biology and epidemiology. *Mycopathologia*, **159(1)**: 129-37.
- Pilotti, C.A. and Bridge, P.D., 2002. Basal Stem Rot: probing the facts. *The Planter* **78(916)**: 365-370.
- Pilotti, C.A., Sanderson, F.R. and Aitken, E.A.B., 2002. Sexuality and interactions of monokaryotic and dikaryotic mycelia of *Ganoderma boninense*. *Mycological Research* **106(11)**: 1315-1322.



- Pilotti, C.A., Sanderson, F.R. and Aitken, E.A.B., 2003. Genetic structure of a population of *Ganoderma boninense* on oil palm. *Plant Pathology* **52**: 455-463.
- Rao, V., Lim, C.C., Chia, C.C. and Teo, K.W., 2003. Studies on *Ganoderma* spread and control. *The Planter* **79(927)**: 367-383.
- Roberto, S.R., Farias, P.S. and Filho, A.B., 2002. Geostical analysis of spatial dynamics of citrus variegated chlorosis. *Fitopatologia Brasileira* **27(6)**.
- Salac, I., Haneklaus, S., Gassner, A. and Schnug, E., 2004. Applicability of geostatistics for identifying spatial patterns indicating the risk of fungal infection and factors involved in sulphur induced resistance (SIR) of oilseed rape. *J. Appl. Ecology*, in press.
- Sanderson, F.R., 2005. An insight into spore dispersal of *Ganoderma boninense* on oil plam. *Mycopathologia*, **159(1)**: 139-141.
- Sariah, M. and Zakaria, H., 2000. The use of soil amendments for the control of BSR of oil palm seedling. In: Flood, J., Bridge, P.D. and Holderness, P. (eds). *Ganoderma Disease of Perennial Crops*, 89-99.
- Singh, G., 1991. Ganoderma-the scourge of oil palm in coastal areas. *The Planter* **67(786)**: 421-444.
- Soepena , H., Purba, R.Y. and Pawirosukarto, S., 2000. A control strategy for BSR (*Ganoderma*) on oil palm. In: Flood, J., Bridge, P.D. and Holderness, P. (eds). *Ganoderma Disease of Perennial Crops*, 83-88.
- Surfer, 1999. *Surfer Version 7 Software Package User's Help*.
- Svrček, M., 1983. *The Hamlyn Book of Mushrooms and Fungi*. Hamlyn, Czechoslovakia.



- Turner, P.D., 1966. *Ganoderma* in oil palm. In: *The Oil palm in Malaya*. Minister of Agriculture and Co-operative. Kuala Lumpur, 109-137.
- Turner, P.D., 1969. Observations on the incidence, effects and control of upper stem rot in oil palm. In: Turner, P.D. (eds). *Progress in Oil Palm*, 143-154.
- Turner, P.D., 1981. *Oil Palm Diseases and Disorders*. The Incorporated Society of Planters, Malaysia.
- Turner, P.D. and Bull, R.A., 1967. *Diseases and Disorders of the Oil Palm in Malaysia*. The Incorporated Society of Planters, Malaysia.
- Turner, P.D. and Gillbanks, R.A., 1974. *Oil Palm Cultivation and Management*. The Incorporated Society of Planters, Malaysia.
- Utomo, C. and Niepold, F., 2000. Development of diagnostic methods for detecting *Ganoderma*-infected oil palms. *Journal of Phytopathology* **148** (9-10): 507-514.
- Van de Lande, H.L. and Zadoks, J.C., 1999. Spatial patterns of spear rot in oil palm plantations in Surinam. *Plant Pathology* **48**: 189-201.
- Waller, J.M. and Holderness, M., 1997. Beverage crops and palms. In: Hillocks, R.J. and Waller, J.M. (eds). *Soilborne Diseases of Tropical Crops*, 232-235.
- Wong, A.H.H. and Cheok, K.S., 2001. Observations of termite-fungus interactions of potential significance to wood biodeterioration and protection. *Timber Technology Bulletin* **24**: 1-9.
- Xu, X.M. and Madden, L.V., 2004. Use of SADIE statistics to study spatial dynamics of plant disease epidemics. *Plant Pathology* **53**: 38-49.

