



**UNIVERSITI PUTRA MALAYSIA**

**EFFECT OF ARBUSCULAR MYCORRHIZA ON OIL PALM  
SEEDLING GROWTH AND DEVELOPMENT OF BASAL STEM ROT  
DISEASE CAUSED BY GANODERMA BONINENSE**

**MARIA VIVA RINI**

**FP 2001 19**

**EFFECT OF ARBUSCULAR MYCORRHIZA ON OIL PALM SEEDLING  
GROWTH AND DEVELOPMENT OF BASAL STEM ROT DISEASE  
CAUSED BY *GANODERMA BONINENSE***

**By**

**MARIA VIVA RINI**

**Thesis Submitted in Fulfilment of the Requirement for the  
Degree of Doctor Philosophy in the Faculty of Agriculture  
Universiti Putra Malaysia**

**June 2001**



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

**EFFECT OF ARBUSCULAR MYCORRHIZA ON OIL PALM SEEDLING GROWTH AND DEVELOPMENT OF BASAL STEM ROT DISEASE CAUSED BY *GANODERMA BONINENSE***

By

**MARIA VIVA RINI**

June 2001

**Chairman : Professor Azizah Hashim, Ph.D.**

**Faculty : Agriculture**

Basal stem rot (BSR) caused by *Ganoderma* species is the most serious disease of oil palm. Infection by the fungi causes significant loss in yield, often resulting in the palm's death as the disease progressed.

Oil palm is a mycotrophic plant. Under natural conditions, the plant is often colonized by arbuscular mycorrhizal (AM) fungi. The current study carried out aimed to evaluate the role of AM in enhancing growth and development of oil palm seedlings and to examine the possibility of using this fungi as a biocontrol agent against basal stem rot (BSR) disease caused by *G. boninense*.



A greenhouse trial was carried out to determine the optimum AM inoculum density for maximum plant growth and AM root colonization. The palms were inoculated with 6 levels of AM inoculum (mixed species of AM spores, extramatrical hyphae and infected root segments of *Setaria ancep*) viz. 0, 20, 40, 60, 80 and 100 g inoculum/plant. Results obtained showed that 40 g inoculum/plant gave maximum growth and percent AM root colonization at 3 months after inoculation. This inoculum level was subsequently used in further experiments. A study was conducted to evaluate the effect of AM on plant growth and development. AM association significantly enhanced palm growth in terms of plant height, total leaf area and dry matter production. Physiological processes such as relative water content, photosynthetic rate and total root phenolic contents were also significantly improved through AM symbiosis. In contrast, stomatal resistance was significantly decreased. AM formation also alters root morphological characteristics. The effect was more profound in the tertiary roots. Number and length of tertiary roots were respectively 63-105% and 26-113% higher in mycorrhizal than in control palms.

The potential of using AM as a biocontrol agent against *G. boninense* was studied by inoculating 5 month old mycorrhizal and nonmycorrhizal seedlings with rubber wood blocks measuring 6x6x12 cm previously colonized by *G. boninense* mycelium. Presence of AM successfully delays the time required by the pathogen to infect and to kill the palms. All nonmycorrhizal seedlings were infected and killed by the



pathogen as early as 6 months after *Ganoderma* inoculation. However, only 75% of the mycorrhizal seedlings showed symptom of BSR infection while 25% of the palms were killed by the pathogen 9 months after *Ganoderma* inoculation. Various sizes of *G. boninense* inoculum block was used in another study: 3x3x6 cm, 3x6x6 cm, 6x6x6 cm and 6x6x12 cm. These respective blocks were used to inoculate 5 month old mycorrhizal and nonmycorrhizal oil palm seedlings. Results obtained confirmed earlier results obtained from the previous study. Mycorrhizal seedlings were more resistant to *G. boninense* infection. Resistance was expressed by a reduction in leaf necrosis, number of rotten primary roots, area of the basal stem tissues that decayed and growth inhibition. However, the potential of AM induced resistance was reduced with increase in size of the pathogen blocks. Spread of *Ganoderma* infection within the primary roots of palms was also significantly affected through AM symbiosis. Results from single root inoculation clearly showed that AM formation significantly decreased the length of primary root that rot as a result of *G. boninense* infection. Length of infected primary root was 7.4 cm and 11.1 cm in mycorrhizal and nonmycorrhizal seedlings respectively.



Abstrak disertasi yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**KESAN MIKORIZA ARBUSKUL KE ATAS TUMBESARAN ANAK  
BENIH KELAPA SAWIT DAN PERKEMBANGAN PENYAKIT REPUT  
PANGKAL BATANG OLEH *GANODERMA BONINENSE***

Oleh

**MARIA VIVA RINI**

**Jun 2001**

**Pengerusi : Profesor Azizah Hashim, Ph.D.**

**Fakulti : Pertanian**

Reput pangkal batang (RPB) yang disebabkan oleh spesies *Ganoderma* merupakan penyakit yang amat serius pada kelapa sawit. Jangkitan oleh kulat ini mengakibatkan menurunnya produksi dan kematian tanaman di peringkat lanjut jangkitan.

Kelapa sawit adalah tanaman 'mikotropik'. Dalam keadaan semula jadi, pokok sering dijangkiti kulat mikoriza arbuskul (MA). Oleh itu, kajian dijalankan untuk menilai peranan MA dalam meningkatkan pertumbuhan anak benih kelapa sawit dan mengkaji potensi kulat MA sebagai ejen kawalan biologi terhadap penyakit reput pangkal batang yang disebabkan oleh kulat *G. boninense*.

Satu kajian rumah kaca telah dijalankan untuk menentukan paras optima inokulum MA untuk tumbesaran pokok yang maksimum. Anak benih sawit telah diinokulasi dengan 6 paras inokulum MA (terdiri dari spora, hifa dan akar *Setaria ancep* yang dijangkiti campuran spesis MA) yaitu 0, 20, 40, 60, 80 dan 100 g inokulum/pokok. Hasil kajian menunjukkan paras inokulum 40 g/pokok memberikan pertumbuhan dan jangkitan akar MA yang maksimum, 3 bulan selepas inokulasi. Paras inokulum ini digunakan untuk kajian selanjutnya. Satu kajian telah dijalankan untuk mengkaji kesan MA ke atas pertumbuhan dan perkembangan pokok. Tinggi pokok, total luas daun dan produksi bahan kering secara bererti ditingkatkan oleh kulat MA. Proses fisiologi seperti kandungan air relatif, kadar fotosintesis dan total sebatian fenol pada akar secara bererti meningkat dengan adanya kulat MA. Sebaliknya, rintangan stomata menurun secara bererti. Kehadiran kulat MA juga telah merubah ciri-ciri morfologi akar. Kesan MA adalah lebih ketara pada akar tertier. Jumlah dan panjang akar tertier masing-masing 63-105 % dan 26-113 % lebih tinggi pada pokok bermikoriza berbanding pokok kawalan.

Kajian menilai potensi penggunaan MA sebagai ejen kawalan biologi keatas kulat *G. boninense* telah dijalankan dengan menginokulasi anak benih bermikoriza atau tanpanya berumur 5 bulan dengan blok kayu getah berukuran 6x6x12 cm yang terlebih dahulu telah dijangkiti oleh miselium *G. boninense*. Kehadiran kulat MA berjaya melambatkan

masa yang diperlukan oleh patogen untuk menjangkiti dan membunuh pokok. Semua pokok tanpa mikoriza telah dijangkiti dan seterusnya mati 6 bulan setelah diinokulasi *Ganoderma*. Walau bagaimanapun, hanya 75% dari pokok bermikoriza menunjukkan gejala penyakit RPB dan hanya 25% pokok yang mati selepas 9 bulan diinokulasi *Ganoderma*. Saiz blok inokulum *G. boninense* yang berbeza telah digunakan pada kajian berikutnya : 3x3x6 cm, 3x6x6 cm, 6x6x6 cm dan 6x6x12 cm. Blok-blok ini telah digunakan untuk menginokulasi anak benih bermikoriza dan tanpa mikoriza berumur 5 bulan. Hasil kajian mengukuhkan lagi hasil kajian sebelumnya iaitu pokok bermikoriza didapati lebih resistan terhadap jangkitan *G. boninense*. Resistansi di tunjukan dengan kurangnya nekrosis pada daun, jumlah akar primer yang reput, area/kawasan pangkal batang yang busuk dan sekatan tumbesaran. Walau bagaimanapun, keberkesanan kulat MA dalam meningkatkan resistansi pokok menurun dengan meningkatnya saiz inokulum patogen. Penyebaran jangkitan *Ganoderma* dalam akar primer secara bererti juga dipengaruhi oleh simbiosis MA. Hasil kajian inokulasi akar tunggal jelas menunjukkan kehadiran MA secara bererti menurunkan panjang akar primer yang reput akibat jangkitan *Ganoderma*. Panjang akar primer yang dijangkiti adalah 7.4 cm dan 11.1 cm masing-masing pada pokok bermikoriza dan tanpa mikoriza.



## ACKNOWLEDGEMENTS

In the name of Allah the Beneficent and the Compassionate. Praise be to Allah SWT., who has given me permission to complete this thesis and enable me to achieve the highest academic degree.

I wish to express my sincere gratitude to Prof. Dr. Azizah Hashim, chairman of the supervisory committee, for her guidance, patience, invaluable advice and constant encouragement during the difficult moments of this study. Her invaluable assistance in the preparation and completion of this manuscript is also highly appreciated. My sincere appreciation also goes to the members of my supervisory committee, Dr. Mahmud Tengku Muda Mohammed, Senior Lecturer at the Department of Agronomy and Dr. Ariffin Darus, Deputy Director-General I (R&D) of Malaysian Palm Oil Board (MPOB, formerly known as PORIM), for their kind advice, suggestion and critically reviewing this manuscript. Special thanks are also extended to Dr. Anuar Abd. Rahim and Dr. Mohd. Ridzwan Abd. Halim for their help on the statistical analysis of this study. Special acknowledgement is also extended to Dr. Idris Abu Seman (MPOB) for his invaluable suggestion and discussion especially for the *Ganoderma* part of this study.

My sincere appreciation also goes to : 1) my lab. colleagues, Dr. Md. Abdus Satter, Sabrina Djunita, Wan Zaleha and Faik ; 2) Faculty technical



staff particularly En. Mazlan, En. Azhar, En. Rahim, En. Ramli, En. Jamil, En. Din, En. Djunaedi, En. Khir, En Nazri, En. Vella, Pn. Fauziah and Pn. Sharimah; 3) MPOB's Pathology Laboratory Staff particularly En. Rosmidi, En. Yunus, En. Ismail and Pn. Noorhashimah; 4) My Indonesian friends especially Bu Nunik, Bu Mahrita, Nunung, Susila, Maiyastri, Ratih, Bu Endang and Tryana; for their help and moral support and in encouraging me on during the most trying period.

To my family, particularly my mother and my late father, brothers and sisters, mother- and father in-law, brothers- and sisters-in-law (especially sister Mahmudah) thank you very much for your unending support, encouragements and prayers.

Special acknowledgements are also extended to the authorities of IRPA project Vot number 53017 for giving me the sponsorship through Graduate Assistantship and for funding this research. To SEAMEO-SEARCA thank you for awarding me the SEARCA-Thesis Grant which partly helps to fund this study.

Last but not least, to my beloved husband, ling Lukman, I am deeply thankful to get your permission to pursue this degree. And to my beloved children Tanukh, Haifa, Puput and Aida, my constant inspiration and strength to complete this study, my sincere appreciation and love for you



all always. To my husband and children, thank you for your sacrifice,  
patience and understanding during the difficult days of our life.



## TABLE OF CONTENTS

|                        |  | Page |
|------------------------|--|------|
| ABSTRACT .....         |  | ii   |
| ABSTRAK .....          |  | v    |
| ACKNOWLEDGEMENTS.....  |  | viii |
| APPROVAL SHEETS .....  |  | xi   |
| DECLARATION FORM ..... |  | xiii |
| LIST OF TABLES .....   |  | xvii |
| LIST OF FIGURES.....   |  | xx   |
| <br><b>CHAPTER</b>     |  |      |
| <b>I</b>               | <b>INTRODUCTION .....</b>  | 1    |
| <b>II</b>              | <b>LITERATURE REVIEW</b>   |      |
|                        | Oil Palm .....   | 9    |
|                        | Botany .....   | 9    |
|                        | Climate .....  | 11   |
|                        | History and its Important .....  | 13   |
|                        | Basal Stem Rot .....   | 15   |
|                        | Occurrence .....   | 15   |
|                        | Importance of BSR .....  | 17   |
|                        | Symptom of BSR .....   | 18   |
|                        | Spread of BSR .....  | 21   |
|                        | Causal Organism .....  | 22   |
|                        | Control of BSR .....   | 23   |
|                        | Mycorrhiza .....   | 25   |
|                        | Type of Mycorrhiza .....   | 26   |
|                        | Arbuscular Mycorrhiza .....  | 27   |
|                        | Characteristic of AM .....   | 29   |
|                        | Hyphae .....   | 29   |
|                        | Arbuscule .....  | 31   |
|                        | Vesicle .....  | 31   |
|                        | Spore .....  | 32   |
|                        | Benefits from AM .....   | 32   |
|                        | Nutrient Uptake .....  | 32   |
|                        | Plant Water Relation .....   | 36   |
|                        | Root Morphology .....  | 38   |
|                        | Biological Control .....   | 40   |
| <b>III</b>             | <b>EFFECT OF AM INOCULUM DENSITY ON GROWTH, ROOT INFECTION AND NUTRIENT UPTAKE OF OIL PALM SEEDLINGS</b> |      |
|                        | Introduction .....   | 44   |
|                        | Objective of the Study .....   | 47   |



|           |  |     |
|-----------|--|-----|
|           | Materials and Methods .....  | 47  |
|           | Plant Germination .....  | 47  |
|           | Soil .....   | 47  |
|           | AM Inoculum and Plant Growth .....   | 48  |
|           | Data Collection .....  | 49  |
|           | Tissue Analysis .....  | 50  |
|           | Assessment of AM Infection .....   | 51  |
|           | Statistical Analysis .....   | 52  |
|           | Results .....  | 52  |
|           | Discussion .....   | 58  |
|           | Conclusion .....   | 62  |
| <b>IV</b> | <b>EFFECT OF AM INOCULATION ON PLANT GROWTH AND DEVELOPMENT</b>  |     |
|           | Introduction .....   | 64  |
|           | Objective of the Study .....   | 66  |
|           | Materials and Methods .....  | 67  |
|           | AM Inoculation and Growth Condition .....  | 67  |
|           | Experimental Design .....  | 67  |
|           | Data Collection .....  | 68  |
|           | Relative Water Content .....   | 68  |
|           | Plant Growth .....   | 70  |
|           | Number and Length of Root Measurement .....  | 70  |
|           | Determination of Total Phenolic .....  | 72  |
|           | Results .....  | 74  |
|           | Mycorrhiza Colonization .....  | 74  |
|           | Plant Growth .....   | 75  |
|           | Phosphorus and Calcium .....   | 78  |
|           | Photosynthesis (Pn), Stomatal Resistance (Rs) and Relative Water Content (RWC) .....                             | 80  |
|           | Root Characteristic .....  | 82  |
|           | Total Phenolic .....   | 87  |
|           | Discussion .....   | 89  |
|           | Conclusion .....   | 97  |
| <b>V</b>  | <b>THE POTENTIAL OF UTILIZING ARBUSCULAR MYCORRHIZA AGAINST <i>GANODERMA BONINENSE</i> IN OIL PALM SEEDLINGS</b> |     |
|           | Introduction .....   | 98  |
|           | Objective of the Study .....   | 102 |
|           | Materials and Methods .....  | 102 |
|           | Experimental Design .....  | 102 |
|           | Seedling Preparation and AM Inoculation .....  | 103 |
|           | Preparation of <i>Ganoderma</i> Inoculum .....   | 103 |
|           | <i>Ganoderma</i> Inoculation .....   | 104 |
|           | Plant Sampling .....   | 106 |
|           | Spore Count .....  | 106 |



|             |   |            |
|-------------|---|------------|
|             | Root Volume Measurement .....   | 107        |
|             | Determination of Chlorophyll Content .....  | 107        |
|             | Determination of Total Fungal and Bacterial<br>Population .....   | 108        |
|             | Analysis of Lignin .....  | 108        |
|             | Results .....   | 110        |
|             | Discussion .....  | 120        |
|             | Conclusion .....  | 127        |
| <b>VI</b>   | <b>EFFECT OF DIFFERENT <i>GANODERMA<br/>BONINENSE</i> INOCULUM DENSITY ON<br/>MYCORRHIZAL AND NONMYCORRHIZAL OIL<br/>PALM SEEDLINGS</b>                   |            |
|             | Introduction .....  | 128        |
|             | Objective of the Study .....  | 130        |
|             | Materials and Methods .....   | 131        |
|             | Experimental Design .....   | 131        |
|             | <i>Ganoderma</i> Inoculation .....  | 132        |
|             | Data Collection .....   | 132        |
|             | Results .....   | 133        |
|             | Discussion .....  | 143        |
|             | Conclusion .....  | 146        |
| <b>VII</b>  | <b>EFFECT OF SINGLE ROOT INOCULATION WITH<br/><i>GANODERMA BONINENSE</i> ON PRIMARY ROOT<br/>OF MYCORRHIZAL AND NONMYCORRHIZAL OIL<br/>PALM SEEDLINGS</b> |            |
|             | Introduction .....  | 147        |
|             | Objective of the Study .....  | 148        |
|             | Materials and Methods .....   | 149        |
|             | Experimental Design .....   | 149        |
|             | <i>Ganoderma</i> Inoculum and Inoculation .....   | 149        |
|             | Data Collection .....   | 151        |
|             | Results .....   | 152        |
|             | Discussion .....  | 153        |
|             | Conclusion .....  | 157        |
| <b>VIII</b> | <b>SUMMARY AND CONCLUSION .....</b>   | <b>158</b> |
|             | REFERENCES .....  | 164        |
|             | VITA .....  | 188        |



## LIST OF TABLES

| Table |  | Page |
|-------|--|------|
| 1     | Classification scheme for Glomalean .....  | 28   |
| 2     | Manuring schedule of oil palm seedlings .....  | 49   |
| 3     | Effect of inoculum density on growth (plant height, number of leaf, total leaf area and root-to-shoot ratio) of oil palm seedlings .....   | 53   |
| 4     | Effect of inoculum density on shoot nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) concentrations of oil palm seedlings ..                           | 56   |
| 5     | Percentage AM colonization of the primary, secondary and tertiary roots of oil palm seedlings versus plant age .....   | 74   |
| 6     | Effect of AM colonization on number of leaf and specific leaf weight of oil palm seedlings at different growth stages .....  | 78   |
| 7     | Effect of AM colonization on phosphorus and calcium concentration (%) in shoot, primary, secondary and tertiary roots of oil palm seedlings at 6 months after AM inoculation ..... | 79   |
| 8     | Effect of AM colonization on dry weight of primary, secondary and tertiary roots of oil palm seedlings at different growth stages .....  | 87   |
| 9     | Effect of AM on specific root length (SRL) of primary, secondary and tertiary roots of oil palm seedling at 6 months after AM inoculation .....                                    | 87   |
| 10    | Effect of AM colonization on total phenolic content (%) in oil palm seedling roots at 5 and 6 month after AM inoculation .....   | 88   |
| 11    | Percentage of infected and dead oil palm seedlings as a result of <i>G. boninense</i> inoculation .....  | 111  |
| 12    | Effect of mycorrhiza and <i>Ganoderma</i> inoculation on percent root colonization by AM in oil palm seedlings ...   | 112  |



|    |  |     |
|----|--|-----|
| 13 | Effect of mycorrhiza and <i>Ganoderma</i> inoculation on number of AM spore per 10 g of rhizosphere soil of oil palm seedlings .....   | 113 |
| 14 | Effect of mycorrhiza and <i>Ganoderma</i> inoculation on total leaf area and dry weight of shoot of oil palm seedlings .....   | 115 |
| 15 | Effect of mycorrhiza and <i>Ganoderma</i> inoculation on dry weight of root and root volume of oil palm seedlings .....  | 116 |
| 16 | Effect of mycorrhiza and <i>Ganoderma</i> inoculation on chlorophyll content, stomatal resistance and photosynthetic rate of oil palm seedlings at 3 months after <i>Ganoderma</i> inoculation .....                           | 117 |
| 17 | Effect of mycorrhiza and <i>Ganoderma</i> inoculation on bacterial and fungal population in the rhizosphere soil of oil palm seedlings .....   | 118 |
| 18 | Effect of mycorrhiza and <i>Ganoderma</i> inoculation on total lignin and calcium concentration in roots of oil palm seedlings .....   | 119 |
| 19 | Percentage of infected oil palm seedlings (based on foliar symptom) due to <i>G. boninense</i> inoculation .....   | 134 |
| 20 | Effect of <i>G. boninense</i> inoculum density on the number of mycorrhizal and nonmycorrhizal seedlings showing each class of BSR disease symptom (base on foliar symptom) at 7 months after <i>Ganoderma</i> inoculation ... | 135 |
| 21 | Effect of <i>G. boninense</i> on percentage AM colonization in oil palm roots .....  | 137 |
| 22 | Dry weight of shoot and roots of mycorrhizal and nonmycorrhizal oil palm seedlings inoculated with five different inoculum density of <i>G. boninense</i> .....  | 138 |
| 23 | Total number of the primary root and percentage of primary root rotted of mycorrhizal and nonmycorrhizal oil palm seedlings inoculated with five different inoculum density of <i>G. boninense</i> .....                       | 139 |





|    |   |     |
|----|---|-----|
| 24 | Total area of base stem and percentage of the base stem decayed of mycorrhizal and nonmycorrhizal oil palm seedlings inoculated with five different inoculum density of <i>G. boninense</i> ..... | 141 |
| 25 | Length of primary roots infected by <i>G. boninense</i> after 6 months of inoculation .....   | 152 |
| 26 | Total phenolic content in mycorrhizal and nonmycorrhizal root after 6 months of <i>G. boninense</i> inoculation .....   | 153 |



## LIST OF FIGURES

| Figure |   | Page |
|--------|---|------|
| 1      | A schematic representation of the oil palm root system  | 12   |
| 2      | Effect of inoculum density on dry weight of shoot ( $P < 0.05$ ) and root ( $P < 0.01$ ) of oil palm seedlings .....  | 54   |
| 3      | Effect of inoculum density on % root infection ( $P < 0.05$ ) of oil palm seedlings .....   | 55   |
| 4      | Relationship between % root colonization and shoot dry weight of oil palm seedling .....  | 57   |
| 5      | Relationship between % root colonization and phosphorus uptake of oil palm seedling .....   | 57   |
| 6      | Oil palm seedlings given 40g AM inoculum versus control (0g) at 3 months after inoculation .....  | 59   |
| 7      | Infra red gas analyzer (Licor Model 6200, USA) .....  | 69   |
| 8      | Measurement of root length with 1 cm <sup>2</sup> grid .....  | 71   |
| 9      | Effect of AM colonization on plant height (A), total leaf area (B) and dry weight of shoot (C) of oil palm seedlings at different growth stages .....                               | 76   |
| 10     | Mycorrhizal and nonmycorrhizal oil palm seedlings at 5 months after AM inoculation .....  | 77   |
| 11     | Relationship between P uptake with dry weight of shoot of oil palm seedlings .....  | 80   |
| 12     | Effect of AM colonization on photosynthetic rate (Pn) (A), stomatal resistance (Rs) (B) and relative water content (RWC) (C) of oil palm seedlings at different growth stages ..... | 81   |
| 13     | Effect of AM colonization on number of primary (A), secondary (B) and tertiary (C) roots of oil palm seedlings .....  | 83   |
| 14     | Relationship between number of secondary root with number of tertiary root produced in oil palm seedlings ..  | 84   |



|    |  |     |
|----|--|-----|
| 15 | Effect of AM colonization on length of primary (A), secondary (B) and tertiary (C) roots of oil palm seedlings .....   | 86  |
| 16 | Rubber wood blocks colonized (right) and uncolonized (left) with <i>G. boninense</i> after 10 weeks of incubation ..   | 105 |
| 17 | AM spores isolated from mycorrhizosphere soil of oil palm seedling .....   | 114 |
| 18 | <i>Ganoderma</i> infected seedling showing smaller newly unfolded leaf .....   | 123 |
| 19 | Sporophore of <i>G. boninense</i> developed at the base stem of infected oil palm seedling .....   | 123 |
| 20 | Mycorrhizal (+M) and nonmycorrhizal (-M) seedlings inoculated with G3 level of <i>G. boninense</i> inoculum at 7 months after inoculation .....                                  | 136 |
| 21 | Relationship between the percentage of the primary root rotted with the number of desiccated leaf in <i>Ganoderma</i> infected seedlings of oil palm .....                       | 140 |
| 22 | Relationship between the percentage of the primary root rotted with the percentage of the base stem decayed in <i>G. boninense</i> infected oil palm seedlings ..                | 142 |
| 23 | A small incision was made at the side of polybag revealing one primary root (A); insertion of the end portion of primary root into the <i>Ganoderma</i> inoculum block (B) ..... | 150 |
| 24 | Putting the block inside a small polybag (A); inoculated oil palm using single root inoculation technique (B) ....   | 151 |



## CHAPTER I

### INTRODUCTION

The oil palm industry is one of the most important agricultural sector in Malaysia. In year 2000, 3.44 million hectares was under oil palm, with a production of about 11.13 million tonnes of crude oil. The export value of oil palm products in 1999 was RM 19.21 billion (MPOB, 2001). However, the oil palm industry is being threatened by a serious fungal disease, known as the basal stem rot (BSR) caused by *Ganoderma* sp.

The BSR affects the root and basal stem portion of the palm. Infection by this fungus begins in the roots and move into the stem causing a dry rot, which eventually lead to death of the palm. Infection of living palms occurs through contact of healthy palm root with the infected root mass or bole tissues, which serve as the inoculum source (Turner, 1981).

An incubation period of several years is believed necessary before the infected palm shows any symptoms of infection. However, Ho and Khairuddin (1995) in their study found that the external symptoms on the three leaf stage oil palm seedlings developed about three months after artificial inoculation with *Ganoderma*.



Earlier, this disease was confined only to the coastal areas and areas having the history of coconut planting. Currently, the incidence of the disease has increased with the fast expanding oil palm cultivation. Palms grown on inland as well as on peat soils have also been reported to be under *Ganoderma* attack (Gurmit, 1995).

Although the BSR disease has long been known, it was earlier thought to be economically unimportant, as infections were recorded on very old palms. At present, the disease is a limitation to production and in certain areas can become catastrophic at a time when the palms are reaching their most productive life (Turner and Bull, 1967; Turner and Gillbanks, 1974; Turner, 1981; Gurmit, 1995). The BSR disease can kill more than 80% of the stand by the time palms are 25 years old. This is especially rampant in areas where oil palms were replanted from coconut or old oil palms. Losses amounting to 50% are common in palms of 15 years, hence reflecting the economic importance of the disease (Gurmit, 1991; Khairudin, 1993). In Sumatra, where a replanting has been carried out simply by pushing over the old stand, with no attempt to remove the BSR affected tissue, palms in the replanted area succumbed to the disease from the second year onwards after planting (Hasan and Turner, 1998). Economic losses usually begin to occur within 10 years with severe losses after 15 years of the normal life span of a planting of about 25 years. Losses in yield as a result of BSR disease arise from negative yield from dead or fallen palms and a reduction in bunch number and

bunch weight of infected palms (Turner, 1981; Khairudin, 1993; Gurmit, 1995). Diseased palms produced 24% to 31% fewer number of bunches and 16% - 27% lighter bunches than those of healthy palms (Khairudin, 1993).

Clean clearing of the former oil palm or coconut stand during replanting is the main method of control currently practised. This is followed by removal of the infected palm to reduce secondary spread (Gurmit, 1991). However, the incidence of this basal stem rot disease is still sufficiently high to warrant concern in the subsequent planting. Biological control using *Trichoderma*, *Aspergillus* and *Penicillium* as well as chemical control using fungicide such as triazole, dazomet have also being evaluated in the field (Ariffin and Idris, 1991a; Gurmit, 1991; Khairuddin, 1993; Sariah *et al.*, 1996 and 1998). However to date neither the biological control nor treatment with fungicides have given satisfactory results.

Mycorrhizal fungi are ubiquitous soil inhabitants and form symbiotic relationship with the roots of majority terrestrial plants. The mutual symbiosis benefits both the host and the fungus (Harley and Smith, 1983). The largest group, which is predominantly associated with agricultural crops, is the arbuscular mycorrhiza (AM) fungi. These fungi penetrate root cortical cells and form special haustoria like structures (arbuscules) that interface with host cytoplasm (Jackson and Mason, 1984). The fungal