



**UNIVERSITI PUTRA MALAYSIA**

**PERFORMANCE OF *Trichoderma harzianum* Rifai AS A BIOLOGICAL  
CONTROL AGENT FOR BASAL STEM ROT OF OIL PALM (*Elaeis  
guineensis* Jacq.) CAUSED BY *Ganoderma boninense* Pat.**

**SHAMALA A/P SUNDRAM**

**FPSK(M) 2005 6**

**PERFORMANCE OF *Trichoderma harzianum* Rifai AS A BIOLOGICAL  
CONTROL AGENT FOR BASAL STEM ROT OF OIL PALM (*Elaeis guineensis*  
Jacq.) CAUSED BY *Ganoderma boninense* Pat.**

**By**

**SHAMALA A/P SUNDRAM**

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

**February 2005**



*This thesis is especially dedicated to my family.....*

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

**PERFORMANCE OF *Trichoderma harzianum* Rifai AS A BIOLOGICAL CONTROL AGENT FOR BASAL STEM ROT OF OIL PALM (*Elaeis guineensis* Jacq.) CAUSED BY *Ganoderma boninense* Pat.**

By

**SHAMALA SUNDRAM**

**February 2005**

**Chairman : Associate Professor Faridah Abdullah, PhD**

**Faculty : Science**

Basal stem rot (BSR) is a major threat to the oil palm industry. The disease is caused by *Ganoderma boninense*, which rots the internal tissues at the trunk base resulting in stem fracture and death of palm. The present study investigated the efficacy of two isolates of *Trichoderma harzianum* (BIO T32 and BIO T66) as potential biological control agents against BSR based on *in vitro* and *in vivo* trials.

The study revealed that treatment applied as a soil drench using conidial suspension (mean of  $1.61 \times 10^8$  spores/ml) of BIO T32 in addition to a *Trichoderma*-incorporated palm press fibre (ppf) surface mulch, performed better with a significant difference compared to the use of BIO T66. The disease severity index (DSI) of the former was 28.35 compared to 76.67 of the latter. BIO T32 was also a competent biological control agent in the delayed treatment given to pre-infected seedlings at 6 weeks before treatment with BIO T32, giving a DSI of 45, which was statistically significant compared to the infected and untreated control seedlings with a DSI of 86.67. In testing the synergistic

effect by combining the 2 isolates, a poorer performance was observed based on the DSI and plant biomass compared to single application of BIO T32. Isolate BIO T66 which showed good antagonistic properties in the *in vitro* assessment was not found to display similar results in the *in vivo* trials.

A series of treatments were evaluated for their potential as a BIO T32 carrier. Out of the 3 studies, only ppf and compost exhibited promising results in their capacity as surface mulches, where treatments with either one gave a DSI of 30. Both are food base carriers for they increased the growth of oil palm seedlings significantly, with compost displaying better results. Treatment with compost in terms of vegetative growth gave the highest plant biomass, leaf area measurement, nitrogen, phosphorus and potassium (NPK) content in the seedlings compared to the other 2 treatments of ppf and the untreated control seedlings.

In total, the experiment revealed that the application of BIO T32 as a single inoculum was the best treatment, giving a DSI of 28.35. Trials using a single application of BIO T66 and BIO T66 mixed with BIO T32 performed poorly, giving a DSI of 76.67 each and were not significantly different from the infected non-treated control plants. An appropriate interval of conidial suspension's application played a pertinent role in the inhibition of disease as demonstrated in the delayed treatment. The application of compost was found to be an interesting alternative to ppf as surface mulch, which functions also as a *Trichoderma* carrier. Finally, in terms of vegetative growth both ppf

and compost as food base carriers significantly increased plant biomass, total leaf area measurement and N uptake compared to the untreated control.

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

**KEBOLEHAN *Trichoderma harzianum* Rifai SEBAGAI AGEN KAWALAN BIOLOGI TERHADAP PENYAKIT REPUT PANGKAL BATANG KELAPA SAWIT (*Elaeis guineensis* Jacq.) YANG DISEBABKAN OLEH *Ganoderma boninense* Pat.**

Oleh

SHAMALA SUNDRAM

Februari 2005

**Pengerusi : Profesor Madya Faridah Abdullah, PhD**

**Fakulti : Sains**

Penyakit reput pangkal batang adalah serius bagi industri pokok kelapa sawit. Penyakit ini disebabkan oleh *Ganoderma boninense* yang menyebabkan reputan pada pangkal pokok yang mengakibatkan kerosakan batang pokok dan akhirnya kematian. Kajian ini menyiasat 2 isolat *Trichoderma harzianum* (BIO T32 dan BIO T66) dalam kebolehan sebagai agen kawalan biologi yang berpotensi terhadap penyakit reput pangkal melalui ujian makmal dan rumah hijau..

Kajian ini telah membuktikan rawatan aplikasi tunggal menggunakan suspensi konidia (purata  $1.61 \times 10^8$  spora/ml) bersama serabut kelapa sawit BIO T32 memberikan keputusan yang lebih baik berbanding dengan BIO T66. Keputusan keparahan index penyakit (DSI) bagi BIO T32 adalah lebih baik dengan 28.35 berbanding BIO T66 dengan 76.67. BIO T32 juga terbukti sebagai agen kawalan biologi yang berpotensi apabila ia memberikan keputusan yang memberangsangkan bagi rawatan 6 minggu lewat

kepada anak pokok kelapa sawit yang dijangkiti EGB 01 berbanding dengan anak pokok yang tidak dirawat (Kawalan II). Dalam menentukan keberkesanan kombinasi 2 isolate tersebut keputusan yang tidak baik diperolehi melalui DSI, berat kering anak pokok jika dibandingkan dengan rawatan menggunakan BIO T32. Isolat BIO T66 yang memberikan keputusan baik dalam ujian *in vitro* tidak memberikan keputusan yang sama dalam ujian *in vivo*.

Beberapa rawatan telah dikaji sebagai pengangkut BIO T32. Dari 3 rawatan yang dikaji, hanya serabut kelapa sawit dan kompos memberikan keputusan yang memberangsangkan dengan DSI 30 untuk kedua-dua rawatan di akhir eksperimen. Kedua-dua agen pengangkut ini juga telah meningkatkan pertumbuhan anak pokok dengan kompos memberikan keputusan yang lebih tinggi dan bererti dalam penyerapan nitrogen, fosforus dan kalium (NPK), berat kering anak pokok serta jumlah luas daun yang paling tinggi berbanding dengan 2 rawatan iaitu serabut kelapa sawit dan kawalan (tidak dirawat).

Secara keseluruhan, kajian ini mendapati rawatan menggunakan BIO T32 secara tunggal lebih berkesan dengan DSI 28.35. Rawatan menggunakan BIO T66 dan kombinasi bersama BIO T32 tidak memberikan keputusan yang memberangsangkan dengan DSI bernilai 76.67 untuk setiap satu. Suspensi konidia yang diberikan pada masa yang betul memberikan keputusan yang memberangsangkan dalam supresi penyakit terutamanya pada anak pokok yang dirawat lewat setelah dijangkiti awal oleh *G.boninense*. Kompos menunjukkan keputusan yang memberangsangkan sebagai agen pengangkut alternatif



kepada serabut kelapa sawit. Akhir sekali, kedua-dua agen iaitu serabut kelapa sawit dan kompos sebagai pengangkut memberikan keputusan yang bererti dalam meningkatkan berat kering anak pokok, jumlah luas daun dan pengambilan nitrogen (N), jika dibandingkan dengan anak pokok yang tidak dirawat.

## ACKNOWLEDGEMENTS

I wish to express my heartfelt thanks to my Masters Program supervisor Associate Professor Dr. Faridah Abdullah for her constant, continuous and invaluable advice, motivation and encouragement throughout the course of this study. I am most indebted for her invaluable information and her constant guidance towards the completion of this thesis. A thank you note also goes to Associate Professor Dr Umi Kalsom Yusof and Associate Professor Dr Zainal Abidin for their support.

I would also like to express my sincere appreciation to Associate Professor Dr. Vijaya Kanapathipillai and Dr. G. M. N. Illias for their support and encouragement in the completion of this thesis. A thank you note goes to my labmate, Miss Jayanthi Nagappan.

My invaluable gratitude goes to my family especially to my mother for her endless effort in persuading me to complete this thesis and not forgetting my sister Subha and brothers Sharma and Vignes for their support and encouragement throughout the finishing point of this thesis. A special thank you goes to Ms Cristina Benjamin for her help and support.

Finally, a special heartfelt appreciation goes to my husband Prajiv, for his endless motivation, assistance, continuous encouragement and guidance during the process of completing this thesis. Thank you for everything.

## TABLE OF CONTENTS

	<b>Page</b>
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	vi
ACKNOWLEDGEMENTS	ix
APPROVAL	x
DECLARATION	xii
LIST OF TABLES	xvii
LIST OF FIGURES	xviii
LIST OF ABBREVIATIONS/NOTATIONS/GLOSSARY OF TERMS	xxiii
 <b>CHAPTER</b>	
<b>I</b>	
INTRODUCTION	1
<b>II</b>	
LITERATURE REVIEW	8
The Oil Palm ( <i>Elaeis guineensis</i> Jacq.)	8
Origin	8
Oil Palm Industry in Malaysia	8
The Botany of Oil Palm	10
Oil Palm Environment	10
Soil Type	10
Nutrients	11
Climate	11
Oil Palm Diseases	11
Root and Butt Rots	11
Stem Diseases	12
Leaf Diseases	13
Diseases of the Fruit and Inflorescences	13
Basal Stem Rot (BSR)	14
Predisposition Factors On The BSR Disease	16
Age of Palms	17
Previous Crop	17
Types of Soils	18
Nutrients in Soil	19
Techniques of Replanting	20
Biological Control	21
<i>Trichoderma</i> – Taxonomy and Morphology	22
<i>Trichoderma</i> as Biological Control Agent – Previous Work	23
Occurrence and Distribution of <i>Trichoderma</i>	25



	Endurance and Propagation of <i>Trichoderma</i> in Soil and Plant Rhizosphere	25
	Mechanism Involved in <i>Trichoderma</i> Antagonism	26
<b>III</b>	<b>MORPHOLOGICAL CHARACTERISTICS, ANTAGONISTIC STUDIES AND PRODUCTION OF DIFFUSIBLE METABOLITES BY SELECTED <i>TRICHODERMA</i> ISOLATES</b>	<b>28</b>
	Introduction	28
	Materials and Methods	33
	Source of <i>Trichoderma</i> Isolates	33
	Colony Characteristics and Culture Morphology	33
	Slide Cultures for Microscopic Characteristics	33
	Effect of Varying Temperature on <i>Trichoderma</i> Isolates	
	Radial Growth	35
	Effect of Varying pH on <i>Trichoderma</i> Isolates Radial Growth	35
	Effect of Varying pH on <i>Trichoderma</i> Isolates Sporulation	36
	Antagonistic Test by Dual Culture	37
	Bilayer Plate Technique to Test Production of Diffusible Metabolites	38
	Results	43
	Colony Morphology and Microscopic Characteristics from Slide Culture	43
	<i>Trichoderma harzianum</i> (Rifai) – BIO T32	43
	<i>Trichoderma harzianum</i> (Rifai) – BIO T66	44
	<i>Trichoderma longibrachiatum</i> (Rifai) – BIO T28	44
	<i>Trichoderma virens</i> (Miller, Giddens & Foster) – BIO T128	45
	Effect of Varying Temperature on <i>Trichoderma</i> Isolates Radial Growth	50
	Effect of Varying pH on <i>Trichoderma</i> Isolates Radial Growth	53
	Effect of Varying pH on <i>Trichoderma</i> Isolates Sporulation	54
	Antagonistic Test by Dual Culture	57
	Bilayer Plate Technique: Production of Diffusible Metabolites	58
	Discussion	61
<b>IV</b>	<b>THE USE OF <i>TRICHODERMA HARZIANUM</i> AS A SINGLE AND A MIXED INOCULUM SOURCE FOR THE SUPPRESSION OF BSR IN GREENHOUSE TRIALS</b>	<b>66</b>
	Introduction	66
	Materials and Methods	69



	Source of Fungal Culture	69
	Source of Seedlings	69
	Source of Potting Media	69
	Preparation of Woodblock Inocula of <i>G. boninense</i> (EGB 01)	69
	Preparation of <i>Trichoderma</i> – incorporated surface mulch	71
	Preparation of <i>Trichoderma</i> Conidial Suspension	71
	Artificial Infection on Oil Palm Seedlings	72
	Experimental Layout	74
	Assessment of Disease Development	77
	Disease Severity Index (DSI)	77
	Dry Weight of Plants	78
	Estimation of Spore Counts	81
	Environmental Factors: Soil Moisture Content and pH	82
	Statistical Analysis	83
Results		84
	Progression of Signs & Symptoms Corresponding to the Disease Classes	84
	Disease Progression Based on Disease Severity Index (DSI)	86
	Dry Weight of Plants	88
	Estimation of <i>Trichoderma</i> Spores: Colony Forming Unit Per Gram Soil	93
	Soil Moisture and pH	95
Discussion		98
<b>V</b>	<b>SELECTION OF AN EFFECTIVE DELIVERY SYSTEM FOR <i>T. HARZIANUM</i> (BIO T32) AND EFFECT OF 2 DELIVERY CARRIERS ON GROWTH OF OIL PALM SEEDLINGS</b>	<b>105</b>
	Introduction	105
	Materials and Methods	109
	Source of Fungal Cultures, Oil Palm Seedlings and Potting Media	109
	Preparation of Woodblocks Inocula of EGB 01 and Method of Infection	109
	Preparation of <i>Trichoderma</i> – Incorporated Surface Mulch	109
	Preparation of <i>Trichoderma</i> – Incorporated Compost	109
	Preparation of <i>Trichoderma</i> Conidial Suspension	110
	Preparation of Hydrogel Suspension	110
	Experiment Layout – Effective Delivery System of BIO T32	111
	Assessment of Effective Delivery System for BIO T32	113
	Disease Severity Index (DSI)	113
	Dry Weight of Plants	113



Estimation of <i>Trichoderma</i> Spore Count	113
Environmental Factors: Soil Moisture and pH	113
Statistical Analysis	113
Experimental layout – Effect of Compost and Surface Mulch on the Growth of Oil Palm Seedlings	114
Assessment of Oil Palm Seedlings Growth	115
Leaf Area Measurement	115
Dry Weight of Plants	115
Nitrogen, Phosphorus and Potassium (NPK) Content in Leaves	115
Statistical Analysis	116
Results	117
Effective Delivery System for <i>T. harzianum</i> (BIO T32) Against EGB 01	117
Disease Establishment based on Progression of Disease Severity Index (DSI)	117
Effective Delivery System: Plant Dry Weight	119
Estimation of <i>Trichoderma</i> Spores by cfu/g soil	121
Soil Moisture and pH	123
Effect of Surface Mulch and Compost on Plant Growth	130
Dry Weight of Plants	130
Leaf Area Measurement	132
Nitrogen, Phosphorus and Potassium (NPK) Content	133
Discussion	135
<b>VI</b> GENERAL DISCUSSION AND CONCLUSION	140
REFERENCES	146
APPENDICES	158
BIODATA OF THE AUTHOR	182



## LIST OF TABLES

Table		Page
3.1	Concentrations of lactic acid and NaoH (250ml for each pH)	36
3.2	Volume of Benlate <sup>®</sup> added in PDA for the respective concentration	40
3.3	Index score for growth of EGB 01 – Bilayer Plate Technique (Etheridge and Craig, 1973)	41
3.4	Effect of varying temperatures on <i>Trichoderma</i> isolates radial growth (pH: 5.68)	51
3.5	Effect of varying pH on <i>Trichoderma</i> isolates radial growth (temperature: 28±°C)	53
3.6	Effect of varying pH on <i>Trichoderma</i> isolates on sporulation (temperature: 28±°C)	54
3.7	Percentage of radial inhibition (PIRG) and colony overgrowth by <i>Trichoderma</i> test isolates	58
3.8	Mean summary on growth index of (EGB 01) on bilayer plates	59
4.1	Disease signs and symptoms corresponding to the disease class	78
4.2	Sequence of disease establishment on Control II seedlings according to disease class	85
4.3	Mean of soil moisture percentage (%) for each group over 22 w. a. i, at 5 and 15 cm depth respectively	96
4.4	Mean of pH for each group over 22 w. a. i, respectively at 5 and 15 cm depth respectively	97
5.1	Progression of Disease Severity Index (DSI) after 24 w. a. i	117
5.2	Mean of soil moisture percentage (%) for each group over 22 w.a. i.	124
5.3	Mean reading of pH for each group over 22 w. a. i, for 5 and 15 cm depth respectively	125

## LIST OF FIGURES

Figure		Page
3.1	A diagram of moist chamber holding slide culture of <i>Trichoderma</i> isolates	34
3.2	An illustration of measurement of radii R1 (top) and (R2) (bottom) of <i>G. boninense</i> (EGB 01) used in the calculation of PIRG	38
3.3	Diagrammatic representation of bilayer plate technique to detect the production and effect of diffusible metabolites from <i>Trichoderma</i> Isolates	42
3.4	Surface and undersurface characteristics of BIO T32 on PDA (A) and microscopic characteristics of BIO T32 showing conidia (B) and conidiophores (C)	46
3.5	Surface and undersurface characteristics of BIO T66 on PDA (A) and microscopic characteristics of BIO T66 showing conidia (B) and conidiophores (C)	47
3.6	Surface and undersurface characteristics of BIO T28 on PDA (A) and microscopic characteristics of BIO T28 showing conidia (B) and conidiophores (C)	48
3.7	Surface and undersurface characteristics of BIO T128 on PDA (A) and microscopic characteristics of BIO T128 showing conidia (B) and conidiophores (C)	49
3.8	Surface and Undersurface of test pathogen EGB 01 ( <i>G. boninense</i> )	50
3.9	Effect of temperature on radial growth of <i>Trichoderma</i> isolates A: BIO T32, B: BIO T66, C: BIO T28 and D: BIO T128. Plates arranged from left to right: 15°C, 25°C, 28°C (middle plate), 35°C and 40°C	52
3.10	Effect of varying pH on radial growth and sporulation of BIO T32. Top from left to right: 2.7, 3.0, 4.0, 5.0; Middle: 5.68 – Control and Bottom; from left to right: 6.0, 7.0, 7.6 and 8.0	55



3.11	Effect of varying pH on radial growth and sporulation of BIO T66. Top from left to right: 2.7, 3.0, 4.0, 5.0; Middle: 5.68 – Control and Bottom; from left to right: 6.0, 7.0, 7.6 and 8.0	55
3.12	Effect of varying pH on radial growth and sporulation of BIO T28. Top from left to right: 2.7, 3.0, 4.0, 5.0; Middle: 5.68 – Control and Bottom; from left to right: 6.0, 7.0, 7.6 and 8.0	56
3.13	Effect of varying pH on radial growth and sporulation of BIO T128. Top from left to right: 2.7, 3.0, 4.0, 5.0; Middle: 5.68 – Control and Bottom; from left to right: 6.0, 7.0, 7.6 and 8.0	56
3.14	Dual culture. Left to right: BIO T28, BIO T32, BIO T66 and BIO T128	57
3.15	Top: Bilayer plate – EGB 01 plated on BIO T28 (PDA + 0.020gL <sup>-1</sup> Benlate®) Middle: Control I – EGB 01 plated only on PDA + 0.020 gL <sup>-1</sup> Benlate®) Bottom: Control 2 – EGB 01 plated only on PDA	59
3.16	Top: Bilayer plate – EGB 01 plated on BIO T28 (PDA + 0.018gL <sup>-1</sup> Benlate®) Middle: Control I – EGB 01 plated only on PDA + 0.018 gL <sup>-1</sup> Benlate®) Bottom: Control 2 – EGB 01 plated only on PDA	60
3.17	Top: Bilayer plate – EGB 01 plated on BIO T28 (PDA + 0.016gL <sup>-1</sup> Benlate®) Middle: Control I – EGB 01 plated only on PDA + 0.016 gL <sup>-1</sup> Benlate®) Bottom: Control 2 – EGB 01 plated only on PDA	60
4.1	Rubber woodblock fully colonized by EGB 01 at 8 weeks of incubation	70
4.2	1 L of conidial suspension of the respective <i>T. harzianum</i> isolates, for the application as a soil drench at 1 L/seedling	73
4.3	Placement of artificial infection seedling in a pot filled with 1/3 of soil	73
4.4	An Illustration of the experimental layout of single (BIO T32/BIO T66), mixed (BIO T32 + BIO T66) and delayed treatments of infected plants using <i>T. harzianum</i>	76
4.5	The production of sporophores from control woodblocks indicating viability of inocula	79

4.6	The disease classes describing the progression of disease signs and symptoms. Top: Class 0 with healthy leaves and class 1 showing leaf necrosis, Middle: Class 2 with mycelia, Bottom: Class 3 with well developed sporophores and class 4 – dead	80
4.7	<i>Trichoderma</i> cfu treated soils observed as green colonies on RBA	83
4.8	Disease Progression of EGB 01 on oil palm seedlings based on disease severity index (DSI) between 0 to 24 w. a. i.	87
4.9	Mean of top dry weight of oil palm seedlings at 24 w. a. i.	89
4.10	Mean of root dry weight of oil palm seedlings at 24 w. a. i.	89
4.11	Seedlings of Control I (uninfected, untreated) uprooted at 24 w. a. i, showing good root volume (DSI=0)	90
4.12	Seedlings from Control II (infected, untreated) uprooted at 24 w. a. i, showing all seedlings succumbed to death with poor root development (DSI=86.67)	90
4.13	Seedlings from Treatment I (infected and treated with BIO T32) uprooted at 24 w. a. i, showing good root volume with few seedlings showing leaf chlorosis (DSI=28.35)	91
4.14	Seedlings from Treatment II (infected and treated with BIO T66 alone) uprooted at 24 w. a. i, showing poor root development with more than 50% seedlings succumbed to death.	91
4.15	Seedlings from Treatment III (infected and treated with mixture of BIO T32 & BIO T66) uprooted at 24 w. a. i, showing similar disease progression with Treatment II (DSI=76.67)	92
4.16	Seedlings from Treatment IV (infected and treated with BIO T32 at 6. w. a. i) uprooted at 24 w. a. i, showing good root mass with almost 50% of seedlings showing leaf chlorosis (DSI=45.0).	92
4.17	Mean reading of cfu/ g soil of <i>T. harzianum</i> at 5 cm depth between 0 to 22 w. a. i.	94
4.18	Mean reading of cfu/ g soil of <i>T. harzianum</i> at 15 cm depth between 0 to 22 w. a. i.	94

5.1	Experiment layout testing delivery system for <i>T. harzianum</i> (BIO T32) against <i>G. boninense</i> (EGB 01)	112
5.2	Illustration of experimental design for the effect of compost and surface mulch on growth of oil palm seedlings	114
5.3	Disease Progression of EGB 01 on oil palm seedlings based on disease severity index (DSI) over 24 w. a. i.	118
5.4	Mean reading of top dry weight of oil palm seedlings at 24 w. a. i.	120
5.5	Mean reading of root dry weight of oil palm seedlings at 24 w. a. i.	120
5.6	Mean reading of cfu/g soil of <i>T. harzianum</i> for at 5 cm depth between 0 to 22 w. a. i.	122
5.7	Mean reading of cfu/g soil of <i>T. harzianum</i> for 15 cm depth between 0 to 22 w. a. i.	122
5.8	Top: Treatment I (ppf surface mulch); Oil palm seedlings infected with EGB 01, which was treated with conidial suspension of BIO T32 (mean of $1.68 \times 10^8$ spores/ml) Bottom: Control I; Oil palm seedlings without infection and treatment.	126
5.9	Top: Treatment I (ppf surface mulch) – Oil palm seedlings infected with EGB 01, which was treated with conidial suspension of BIO T32 (mean of $1.68 \times 10^8$ spores/ml). Bottom: Control II – Oil palm seedlings infected with EGB 01 without treatment.	126
5.10	Top: Control I – Oil palm seedlings without infection and treatment. Bottom: Treatment II (compost) – Oil palm seedlings infected with EGB 01, which was treated with conidial suspension of BIO T32 ( $1.67 \times 10^8$ spores/ml)	127
5.11	Top: Treatment II (compost) – Oil palm seedlings infected with EGB 01, which was treated with conidial suspension of BIO T32 ( $1.67 \times 10^8$ spores/ml). Bottom: Control II – Oil palm seedlings infected with EGB 01 without treatment	127

5.12	Top: Control I – Oil palm seedlings without infection and treatment. Bottom: Treatment III (conidial suspension) – Oil palm seedlings infected with EGB 01 which was treated with conidial suspension of BIO T32 ( $1.68 \times 10^8$ spores/ml)	128
5.13	Top: Control II – Oil palm seedlings infected with EGB 01 without treatment; Bottom; Treatment III (conidial suspension) - Seedlings infected with EGB 01 which was treated with only conidial suspension of BIO T32 ( $1.68 \times 10^8$ spores/ml)	128
5.14	Top: Treatment IV (Hydrogel) – Oil palm seedlings infected with EGB 01 which was treated with hydrogel suspension of BIO T32 ( $1.67 \times 10^8$ spores/ml). Bottom: Control I – Oil palm seedlings without infection and treatment.	129
5.15	Top: Treatment IV - Seedlings infected with EGB 01, which was treated with hydrogel suspension of BIO T32 ( $1.67 \times 10^8$ spores/ml). Bottom: Control II – Oil palm seedlings infected with EGB 01 without treatment	129
5.16	Mean reading of top dry weight over 24 weeks	130
5.17	Mean reading of root dry weight over 24 weeks	131
5.18	Mean reading of leaf area measurement on 16 <sup>th</sup> week of experiment	132
5.19	Mean reading of NPK percentage in oil palm seedlings	133
5.20	Comparison of seedlings of control (left) and seedlings treated with compost (right)	134
5.21	Up rooted seedlings of compost (right) being compared with seedlings of control (left)	134

## LIST OF ABBREVIATIONS

DSI	:	Disease Severity Index
ANOVA	:	Analysis of Variance
DMRT	:	Duncan's Multiple Range Test
PDA	:	Potato Dextrose Agar
MEA	:	Malt Extract Agar
TDW	:	Top dry weight
RDW	:	Root dry weight
PIRG	:	Percentage Inhibition of Radial Growth
NPK	:	Nitrogen, Phosphorus and Potassium
ppf	:	palm press fibre
cfu	:	colony forming unit
w. a. i.	:	weeks after infection
g	:	gram
m	:	meter
ml	:	mililitres
L	:	liter
d	:	diameter
cm	:	centimeter
Kg	:	kilogram
C	:	celcius
rpm	:	rotation per minute

## CHAPTER I

### INTRODUCTION

The oil palm, *Elaeis guineensis*, is the highest yielding among the oil-producing crops (Ariffin *et al.*, 2000). It is an important species in the tropical regions because of its two main raw materials namely; palm oil and palm kernel oil. Palm oil commands an average yield of about 4 tonnes oil ha<sup>-1</sup> year<sup>-1</sup>. In the year 2002, Malaysia produced 60% of the world's palm oil with a total production of about 11 million tonnes (World Oils & Fats, 2002).

Like any other crop, the oil palm also faces a lot of pest and disease (P&D) tribulations. From seed germination right up to field planting, the crop is exposed to several P&D problems, some of which is caused by fungi. Some of the P&D problems faced by oil palm industry are the basal stem rot, brown germ, upper stem rot, *Rhinoceros* beetles and bagworm (Turner, 1981). Among these, the current most serious disease is Basal Stem Rot (BSR). For the past 50 years or more, BSR had been causing serious damage to the oil palm plantation in Malaysia. The disease is also prevalent in Indonesia, Zaire, Ghana, Nigeria, Cameroon, San Tome, Principe, Angola, Rhodesia and Papua New Guinea (PNG) (Turner, 1981) with incidence being relatively low in PNG (Pilotti, 2001).

The causal pathogen of this disease is the fungus *Ganoderma*. Not only does it attack oil palms, it is also the causal agent of root and stem rots of other crops namely; coconut,