



UNIVERSITI PUTRA MALAYSIA

**ISOLATION AND CHARACTERIZATION OF PHENYLALANINE
AMMONIA LYASE (PAL) AND OTHER DEFENCE RESPONSE
GENES FROM OIL PALM (*ELAIES GUINEENSIS* JACQ.)**

HWANG SIAW SAN

FSMB 2002 7

**ISOLATION AND CHARACTERIZATION OF PHENYLALANINE AMMONIA
LYASE (PAL) AND OTHER DEFENCE RESPONSE GENES FROM OIL PALM
(*ELAIES GUINEENSIS* JACQ.)**

By

HWANG SIAW SAN

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

FEBRUARY 2002



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

**ISOLATION AND CHARACTERISATION OF PHENYLALANINE AMMONIA
LYASE (PAL) AND OTHER DEFENSE RESPONSE GENES FROM OIL PALM
(*ELAIES GUINEENSIS* JACQ.)**

By

HWANG SIAW SAN

February 2002

Chairman: Tan Siang Hee, Ph.D.

Faculty: Faculty of Food Science and Biotechnology

Enhanced disease resistance and plant defense response against pathogen attack and environmental stresses have always been important targets of plant biotechnology. The activation of the defense response requires the recognition of an elicitor and the subsequent initiation of a signal transduction pathway, which then leads to the activation of defense genes and the production of phytoalexins. Plants respond to pathogen attack and environmental stimuli by activating a wide variety of defense reactions including transcriptional activation of genes involved in phenylpropanoid biosynthesis, accumulation of antimicrobial phytoalexins, and ethylene production.

Phenylpropanoid metabolism is a plant specific pathway that leads to the production of secondary metabolites including isoflavonoid phytoalexins, lignin, flavonoid pigments and UV protectants such as furanocoumarin. Here, we report the isolation of several different clones that are involved in the plant defense response by screening of oil palm zygotic embryo and suspension culture cDNA libraries. These clones include



phenylalanine ammonia- lyase (PAL) (4-4A, 11F1 and 12B1), S-adenosylmethionine synthetase I (Adomet synthetase I) (11A1), peroxidase (7A2), chitinase III (4A3), calmodulin (3E2), and beta-ketoacyl-CoA synthase (KCS) (3G1).

PAL and peroxidase are enzymes involved in the phenylpropanoid pathway and lignin biosynthesis. Adomet synthetase I is a precursor for ethylene biosynthesis in plants and also acts as a methylating agent in cells. Calmodulin is a calcium-binding molecule that is involved in the signal transduction pathway during the plant defense response. On the other hand, chitinase III is one of the pathogenesis-related (PR) proteins whereas KCS plays an important role in plant protection through the production of epicuticular waxes on the plant surface.

Northern blot analyses have demonstrated the differential expression of PAL and Adomet synthetase I in response to wounding, UV irradiation and ethephon treatments. In addition, expression of PAL and Chitinase III in different tissues has also been studied. Southern blot analyses demonstrated that PAL and calmodulin appear as a single copy gene in the oil palm genome. Two copies of KCS and two or more copies of Adomet synthetase I, chitinase III, and peroxidase have been detected in the oil palm genome. In these experiments, the combination of a PCR-based screening technique and plaque lift hybridisation has proved to be an effective method, especially for the isolation of a specific gene from a cDNA library. Besides, this method is also less time consuming and less laborious.



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

PENGASINGAN DAN PENCIRIAN PHENYLALANINE AMMONIA LYASE (PAL) DAN GEN-GEN PERTAHANAN YANG LAIN DARI KELAPA SAWIT (*ELAIES GUINEENSIS* JACQ.)

Oleh

HWANG SIAW SAN

Februari 2002

Pengerusi: Tan Siang Hee, Ph.D.

Faculty: Fakulti Sains Makanan dan Bioteknologi

Peningkatan taraf pertahanan tumbuhan terhadap serangan penyakit and tekanan persekitaran sentiasa menjadi tumpuan kepada bioteknologi tumbuhan hari ini. Perangsangan reaksi pertahanan tumbuhan memerlukan penghasilan elisitor dan kehadiran satu proses signal transduksi yang akan membawa kepada ekspresi gen-gen pertahanan dan penghasilan 'phytoalexin'. Tumbuhan bertindak balas terhadap serangan patogen dan rangsangan persekitaran dengan menghasilkan reaksi pertahanan termasuk transkripsional gen yang terlibat dalam penghasilan 'phenylpropanoid', pengumpulan antimikrobial 'phytoalexin', dan penghasilan etilena.

Metabolisma phenylpropanoid adalah satu proses spesifik yang membawa kepada penghasilan produk asli tumbuhan termasuk 'isoflavonoid phytoalexin', lignin, pigmen flavonoid dan bahan lindungan UV seperti 'furanocoumarin'. Di sini, kami melaporkan pengasingan gen-gen yang bertanggungjawab ke atas tindak balas pertahanan tumbuhan dengan penyaringan koleksi cDNA daripada embrio zigotik dan kultur ampaiian kelapa



sawit. Klon-klon ini termasuk phenylalanine ammonia-lyase (PAL), S-adenosylmethionine synthetase I (Adomet synthetase I), peroksidase, kitinase III, calmodulin, dan β -ketoacyl-CoA synthase (KCS).

PAL dan peroksidase adalah enzim yang terlibat dalam metabolisme 'phenylpropanoid' dan penghasilan lignin. Adomet synthetase I adalah prekursor kepada penghasilan etilena dan ia juga merupakan satu agen metilasi dalam sel. Selain itu, calmodulin adalah molekul yang terikat kepada kalsium yang terlibat dalam proses signal transduksi semasa tindak balas pertahanan tumbuhan. Di samping itu, kitinase III adalah salah satu daripada patogenesis protein, manakala KCS memainkan satu peranan penting dalam perlindungan tumbuhan melalui penghasilan lilin kutikel di permukaan tumbuhan.

'Northern blot' analisis menunjukkan ekspresi yang berlainan untuk PAL dan Adomet synthetase I terhadap perlukaan dan radiasi UV. Selain itu, ekspresi PAL dan kitinase III dalam tisu yang berlainan juga diselidiki. 'Southern blot' analisis mendemonstrasikan bahawa PAL dan calmodulin berkemungkinan wujud sebagai gen tunggal dalam genomik kelapa sawit. Lebih daripada satu gen dijangkakan terdapat dalam genomik kelapa sawit untuk Adomet synthetase I, kitinase III, peroksidase, dan KCS. Dalam eksperimen ini, penggunaan teknik penyaringan koleksi cDNA melalui PCR dan 'plaque lift' hybridisasi telah dibuktikan sebagai satu kaedah yang efektif, terutamanya untuk pengasingan gen-gen spesifik. Selain itu, ia juga menjimatkan masa dan tenaga kerja.

ACKNOWLEDGEMENTS

Firstly and foremost, I would like to dedicate my sincere appreciation and whole-hearted gratitude to Dr. Tan Siang Hee for his constant guidance, concern, understanding, encouragement, advice and remarkable patience in this project. My heartfelt thanks is also dedicated to my supervisory committee members, Dr. Harikrishna, especially for his constant advice and guidance; and Dr. Cheah Suan Choo (MPOB) for all her support. I also wish to thank MPOB for funding this project (Grant No. 63534). My special thanks also goes to Dr. Ho Chai Ling for all her advice and encouragement.

My sincere appreciation also dedicated to all the members in Genetic Lab especially Wan Chin and Au for their assistance and suggestions. Also to Mr. Ong, Parames, Jason, Mei Chooi, Yang Ping, Chee How, Wai Har, Nancy, Mus, Choong, Weng Wah, Pick Kuen, Siti and Pau Then for their advice and assistance throughout the project. I would like to extend my sincere gratitude to members in MPOB especially Mei, Siew Eng, Zhaidah, kak Azizah and Dr. Sharifah for all their helps and support as well. My special thanks also goes to my dearest housemates, especially Ee Fong, Chin Peng, Peng Kong and Sock Kun for their understanding, kindness and encouragement. Finally, I would like to express my heartiest gratitude and appreciation to my beloved parents, husband, brother and sister for their inspiration, understanding, encouragement and constant moral support throughout the years of my study. It is their unrelenting love that keeps my spirit alive and brings me strength to face with whatever challenges in life. Thank you and I love you all so much!



This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science

AINI IDERIS, Ph.D.
Professor
Dean of Graduate School,
Universiti Putra Malaysia

Date:



DECLARATION

I hereby declare that the thesis is based on my original work except for equations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

(HWANG SIAW SAN)

Date:

TABLE OF CONTENTS

	Page
ABSTRACT	ii
ABSTRAK	iv
ACKNOWLEDGEMENTS	vi
APPROVAL SHEETS	vii
DECLARATION FORM	ix
LIST OF TABLES	xii
LIST OF FIGURES	xiii
ABBREVIATIONS	xviii
CHAPTER	
I INTRODUCTION	1
II LITERATURE REVIEW	3
The Botany of Oil Palm	3
Diseases in Oil Palm	5
Mechanism of Plant Defense Response	6
Signal Transduction Pathway	9
Activation of Elicitor-Responsive Genes	17
Phenylpropanoid Pathway	20
Lignin Biosynthesis in Plants	25
Phenylalanine Ammonia Lyase (PAL)	28
Gene Specific Expression of PAL	30
Cis-Elements and Transcription Factors of PAL	33
S-adenosylmethionine Synthetase	38
Calmodulin	48
Chitinase III	55
Peroxidase	59
Beta-ketoacyl-CoA Synthase (KCS)	61
III MATERIALS AND METHODS	65
Plant Materials and Tissue Induction	65
RNA Extraction	66
Isolation of Total Genomic DNA	69
PCR Cloning of Partial Phenylalanine Ammonia Lyase (PAL) cDNA	70
First-strand cDNA Synthesis and RT-PCR	70
Analysis of Cloned PCR Fragment	72
Isolation of Plasmid DNA	72
Screening of Plasmid with Insert	73



Automated DNA Sequencing	73
Sample Preparation and Cycle Sequencing	73
Preparation of Acrylamide Denaturing Gel	74
Screening of Oil Palm Zygotic Embryo and Suspension Culture cDNA Libraries	74
Screening of Oil Palm Zygotic Embryo cDNA Library	75
Amplification of cDNA and PCR Analysis	75
Screening of Oil Palm Suspension culture cDNA Library	76
Preparation of Bacterial Culture for Infection	76
Plaque Lift Hybridization	77
Radiolabelling of DNA Probe	78
Prehybridisation and Hybridisation of Membranes	78
Plaques Corring	79
Single Clone <i>In-vivo</i> Excision	80
Sequence Analysis	80
Northern Blot Analysis	81
Southern Blot Analysis	81
Rapid Amplification of cDNA Ends (RACE PCR)	82
IV RESULTS AND DISCUSSION	83
Cloning of Partial PAL cDNA by RT-PCR	83
Screening of the Oil Palm Zygotic Embryo cDNA Library	84
PCR-based Screening	84
Plaque Lift Hybridization	87
Screening of Oil Palm Suspension Culture cDNA Library	90
PCR-based Screening	90
Sequences Analyses	94
Clones 4-4A, 11F1, and 12 B1	94
Clone 11A1	104
Clone 3E2	114
Clone 7A2	117
Clone 4A3	121
Clone 3G1	125
Northern Blot Analyses	141
Southern Blot Analyses	154
V CONCLUSION	158
BIBLIOGRAPHY	162
APPENDICES	195
Appendix I	195
Appendix II	196
Appendix III	197
BIODATA OF THE AUTHOR	198



LIST OF TABLES

Table		Page
4.1	Sequences analyses of potential cDNA clones according to BLASTX results.	93



LIST OF FIGURES

Figure		Page
2.1	Major components of the signal-transduction chain from elicitor perception to gene activation in cultured parsley cells.	13
2.2	Elicitor-inducible reactions of primary and secondary metabolism in cultured parsley cells.	15
2.3	Schematic drawing of defense responses activated in a plant-pathogen interaction.	16
2.4	Metabolic interconnections among various selected elicitor-inducible reactions in cultured parsley cells.	18
2.5	Schematic diagram of the pivotal role of C4H as a functional link between the cytosolic enzymes of general phenylpropanoid metabolism, PAL and 4CL, and the membrane-associated electron-transfer reactions catalyzed by CPR.	19
2.6	Schematic view of some branches of phenylpropanoid metabolism.	21
2.7	Biosynthetic pathways for 3-deoxyanthocyanidins and anthocyanidins.	24
2.8	OMT-catalyzed reactions in the general phenylpropanoid pathway.	27
2.9	Scheme indicating the enzymatic steps and the primary metabolites serving as substrates for the biosynthesis of variously substituted flavone and flavonol glycosides in UV-irradiated parsley cells.	29
2.10	Schematic representation of pathogen responsive cis-acting elements (P-, L-, H-boxes) and their cognate interacting factors (BPF-1, MYB, G/HBF-1, KAP1/2).	35
2.11	Summary of current understanding of the roles of MYB-related transcription factors in controlling phenylpropanoid metabolism from phenylalanine.	37
2.12	Relationships among methionine, threonine, Adomet, polyamines, biotin, and ethylene biosynthetic pathways in higher plants.	39
2.13	Illustration of the AdoMet synthetase active site.	40
2.14	Schematic diagram of the ethylene biosynthesis pathway in plants.	42
2.15	Three-dimensional structure of mammalian calmodulin.	48



2.16	Domain structure of calcium-dependent protein kinase or calmodulin-like domain protein kinases (CKPKs) and three related protein kinases.	53
2.17	Ca ²⁺ -bound-calmodulin-mediated signal transduction in plants.	54
2.18	Crystal structure with bound polysaccharide ligands (dot surfaces), showing the location and frequency of amino acid replacements for plant class III chitinase.	57
4.1	RNA gel picture showing 18S and 28S RNA extracted from oil palm young leaves.	83
4.2	RT-PCR products of partial PAL cDNA separated on 1.0% agarose gel.	84
4.3	Secondary screening of zygotic embryo cDNA library with degenerate primers.	85
4.4	Tertiary screening of zygotic embryo cDNA library with degenerate primers.	85
4.5	Fourth round screening of zygotic embryo cDNA library with gene specific primers.	86
4.6	Nested PCR products for the fourth found of zygotic embryo cDNA screening using nested primers.	86
4.7	Fourth round screening of zygotic embryo cDNA library by using plaque lift hybridization technique with radiolabeled partial PAL cDNA as probe.	87
4.8A	PCR products amplified by using primers T3 and T7.	89
4.8B	PCR products amplified by using primers T3 and T7.	89
4.9	Primary PCR screening of suspension culture cDNA library using gene specific primers.	90
4.10	Secondary screening of suspension culture cDNA library by using plaque lift hybridization technique with radiolabeled partial PAL cDNA as probe.	91
4.11	Tertiary screening of suspension culture cDNA library by using plaque lift hybridization technique with radiolabeled partial PAL cDNA as probe.	91

4.12	The nucleotide sequence of partial 4-4A and its deduced amino acid sequence.	94
4.13	Aligned amino acid sequences of clones 4-4A, 11F1, and 12B1.	97
4.14	Aligned amino acids sequence of clone 4-4A with the sequences of PAL from different plant species.	99
4.15	Nucleotide sequence of clone 11A1 and its deduced amino acid sequence.	104
4.16	Aligned amino acid sequences of clone 11A1 with the sequences of Adomet synthetase I from different plant species.	106
4.17	Aligned amino acid sequence of clone 11A1 with Adomet synthetase II and III from different plant species.	109
4.18	Aligned amino acid sequence of clone 11A1 with the sequences of Adomet synthetae from fission yeast, human being, rattus, and <i>candida albican</i> .	112
4.19	Nucleotide sequence of clone 3E2 and its deduced amino acid sequence.	115
4.20	Aligned amino acid sequence of clone 3E2 with sequences of calmodulins from different plant species.	116
4.21	Nucleotide sequence of clone 7A2 and its deduced amino acid sequence.	117
4.22	Aligned amino acid of clone 7A2 with sequences of peroxidases from different plant species.	119
4.23	Nucleotide sequence of clone 4A3 with its deduced amino acid.	122
4.24	Aligned amino acid sequence of clone 4A3 with sequences of chitinase III from different plant species.	123
4.25	Nucleotide sequence of clone 3G1 with its amino acid sequence.	126
4.26	Aligned amino acid sequence of clone 3G1 with sequences of KCS from different plant species.	128
4.27	Aligned amino acid sequence of clone 3G1 with sequences of chalcone synthase (CHS), anther specific protein (ASP), fiddlehead protein (FDH), CUT1, and fatty acid elongase (FAE).	131



4.28	RNA gel blot analyses PAL, Adomet synthetase I (AdoI), chitinase III (ChiIII) and cyclophilin in response to wounding of one-month old leave tissues of oil palm <i>in vitro</i> seedlings.	142
4.29	RNA gel blot analyses of PAL, Adomet synthetase I (AdoI), chitinase III (ChiIII), and cyclophilin (Cyc) in response to wounding of 3 months old leave tissues of oil palm <i>in vitro</i> seedlings.	143
4.30	RNA gel blot analyses of PAL, Adomet synthetase I (AdoI), chitinase III (ChiIII), and cyclophilin (Cyc) in response to wounding of 3 months old stem tissues of oil palm <i>in vitro</i> seedlings.	143
4.31	RNA gel blot analyses of PAL, ChiIII, Cyc and 18S RNA in response to mercury chloride treatment of one-month old leave tissues of oil palm <i>in vitro</i> seedlings.	144
4.32	RNA gel blot analyses of PAL, Adomet synthetase I (AdoI), chitinase III (ChiIII), and 18S RNA in response to UV irradiation of one-month old oil palm <i>in vitro</i> seedlings.	145
4.33	RNA gel blot analyses of Adomet synthetase I (AdoI) and actin in response to 0.1, 1.0, and 5.0 mg of ethephon treatments of leave and root tissues of 3 months old oil palm seedlings after 48 hours.	147
4.34	RNA gel blot analyses of PAL, AdoI and actin in response to 0.1 and 1.0 mg of ethephon treatments of root tissues of 3 months 0.2 old oil palm seedlings after 2 hrs.	148
4.35	RNA gel blot analyses on tissue expression patterns of PAL in different tissues of oil palm.	149
4.36	RNA gel blot analyses on tissue expression patterns of ChiIII in different tissues of oil palm.	149
4.37	Southern blot analyses of clone 4-4A (B) and 4A3 (C) for oil palm total DNA.	154
4.38	Southern blot analyses of clone 11A1(B) and 3E2 (C) for oil palm total DNA.	155
4.39	Southern blot analyses of clone 7A2 (B) and 3G1 (C) for oil palm total DNA.	156



LIST OF ABBREVIATIONS

A ₂₆₀	absorbance at 260 nm
2-BE	ethylene glycol monobutyl ether
BLAST	Basic Local Alignment Research Tool
4CH	cinnamic acid 4-hydroxylase
4CL	4-coumarate:CoA ligase
ACC synthase	1-aminocyclopropane-1-carboxylic acid
ACP	acyl carrier protein
AOPP	L- α -aminooxy- β -phenylpropionic acid
Avr gene	avirulence gene
C ₂ H ₂	ethylene
CAD	cinnamyl-alcohol-dehydrogenase
CaM	calmodulin
CCR	cinnamoyl-CoA reductase
cDNA	complementary deoxyribonucleic acid
CHS	chalcone synthase
DEPC	diethyl pyrocarbonate
DNA	deoxyribonucleic acid
dNTPs	dioxynucleoside triphosphate
DTT	dithiothreitol
EDTA	ethylenediamine tetraacetic acid
EGTA	ethylene glycol-bis(β -aminoethylether)- <i>N,N,N',N'</i> -tetraacetic acid
ERE	ethylene responsive element



FAE	fatty acid elongase
GTE	Glucose-Tris-EDTA
GTP	guanosine triphosphate
GUS	β -glucuronidase
hr	hour
HR	hypersensitive reaction
HRGP	hydroxyproline-rich glycoprotein
Jacq.	Jacquin
KCl	potassium chloride
KCS	beta ketoacylCoA synthase
kb	kilobase
LAR	localized acquired resistance
LB	Luria-Bertani
LiCl	lithium chloride
LRRs	leucine rich repeats
M	Molar
MAP	mitogen activated protein
mg	milligram
MgCl ₂	magnesium chloride
MgSO ₄	magnesium sulfate
min	minute(s)
mM	millimolar
MOPS	3-(N-morpholino) propanesulfonic acid
mRNA	messenger ribonucleic acid



MYB	myoblastosis
NaCl	sodium chloride
NaOH	sodium hydroxide
NCBI	National Center for Biotechnology Information
ng	nanogram
OD	Optical density
oligo(dT)	oligodeoxythymidylic acid
OMT	<i>O</i> -methyltransferase
ORF	open reading frame
PAI	phosphoribosyl anthronilase isomerase
PAL	phenylalanine ammonia-lyase
PCI	phenol:chloroform:isoamyl
PCR	polymerase chain reaction
pfu	plaque-forming units
poly(A) ⁺	polyadenylated (mRNA)
POX	peroxidase
Ptil	Pto interacting 1
PVPP	polyvinylpolypyrrolidone
R gene	resistance gene
RACE	rapid amplification of cDNA ends
RNA	ribonucleic acid
RNase	ribonuclease
ROS	reactive oxygen species



rpm	revolution per minute
RT	reverse transcriptase
SAH/SHH	S-adenosyl-L-homocysteine hydrolase
SAR	systemic acquired resistance
SDS	sodium dodecyl sulfate
sec	second
SMS/SAM	S-adenosyl-L-methionine synthetase
SSC	sodium chloride/sodium citrate
TAE	Tris/acetate buffer
TEMED	<i>N,N,N',N'</i> -tetramethyl-ethylenediamine
TMV	tobacco mosaic virus
TPNS	triisopropylnaphtalene sulfonic acid
Tris-CL	Tris hydrochloride
TyrDC	tyrosine decarboxylase
UTR	untranslated region
µg	microgram
µl	microliter
UV	Ultraviolet
VLCFs	very long chain fatty acids
V/v	volume per volume
WGA	wheat germ agglutinin
w/v	weight per volume



CHAPTER I

INTRODUCTION

Palm oil is one of the 17 major oils and fats that are produced and traded in the world. Malaysia, with 8.315 million tones of palm oil produced in 1998 is the world' s leading producer of palm oil, which accounted for 49.5% of the total palm oil produced in the world (Basiron *et al.*, 1999). The oil palm industry in Malaysia is expected to attain a production level of 12.1 million tones by the year 2020 (Basiron *et al.*, 1999).

Various diseases caused by bacterial and fungus that attack oil palm have been reported in Malaysia. Among these, basal stem and root rots caused by *Ganoderma* have resulted severe losses in Malaysia as well as South East Asia. It is important that effective techniques and strategies are developed in order to control plant diseases. However, the application of the molecular biology approach to enhance disease resistance in oil palm is in its infancy. In addition, there is still very limited information on the molecular biology of defense or stress response mechanisms in oil palm that are available. Besides, no studies have reported on defense or stress responsive genes expression in oil palm, especially those related to the defense signal transduction pathway and secondary metabolites biosynthesis.

Understanding the mechanisms of plant defense response and the function of disease resistance genes that govern the resistance of plants to pathogens or stresses have advanced rapidly recently. Major advances in cloning and sequencing of the related genes are providing valuable information on the basis of their roles in defense



mechanisms and recognitional specificities. This further offer the opportunity to engineer genes that regulate an array of defense responses, and enhanced resistance can be obtained with the transformation of cloned defense response genes into crop species to produce transgenic lines.

Isolation and characterization of cDNA clones encoding disease resistance or stress responsive genes is a preliminary step in the commencement of a molecular biological study of oil palm defense response mechanisms. Therefore, fundamental research on genes involved in the defense signal transduction pathway, phenylpropanoid biosynthesis, and genes that encode pathogenesis-related (PR) proteins is needed to provide a better understanding of the molecular mechanisms involved during oil palm defense responses.

The objective of this study was to isolate and characterise defense response genes from an oil palm zygotic embryo cDNA library and suspension culture cDNA library. The isolated genes were characterized for their stress response properties by studying their expression patterns during different stress treatments through northern blot analysis. Besides, the copy number of these genes that are present in the oil palm genome was also estimated.

Therefore, it is hoped that this preliminary study will provide a more meaningful understanding of the genes involved during oil palm defense and stress response mechanisms, thus allow this information to be utilized and be applied to facilitate engineering for disease resistance in oil palm in the future.

CHAPTER II

LITERATURE REVIEWS

The Botany of Oil Palm

The oil palm (*Elaeis guineensis* Jacq.) is grouped under the same tribe with coconut, *Coccothrinaceae*, in the family of *Palmae*. The oil palm originated from the Guinea Coast, West Africa, was first introduced to Malaysia in the year 1871 (Hartley, 1988). The main commercial planting materials in Malaysia were tenera's (*dura* x *pisifera*) since 1961 (Tan, 1983).

The palm has a crown of pinnate fronds on a vascular stem (Corley & Gray, 1976a). There is only one terminal growing point in oil palm (Rees, 1964). The apical meristem is located at the centre of a shallow depression formed by the primordial leaves and other tissues within the crown of the palm. It gives rise to very little stem tissue, producing mainly leaf primordia (William & Hsu, 1970). The leaf primodium arises as a lateral structure from the shoot apex and will give rise to the petiole, rachis and lamina wings or leaflets. The fronds are arranged in two opposing sets of spirals, whereby every 8th frond falls on one spiral and every 13th on the opposing set (Hartley, 1977). The mature palm may carry a crown of 25-40 fronds. The frond is attached to the stem by a broad clasping base, which narrows into a spiny petiole. The stalk is continued right through the length of the frond as the rachis. Stem tissue is formed at a later stage from a meristem, which is continuous with the bases of the fronds. Oil palm has a typical fibrous root system common to monocotyledonous plants (William & Hsu, 1970).

The palm is monoecious bearing male and female inflorescences in alternating cycles. A hermaphrodite inflorescence may also occur at certain stages. In a potentially female primodium, the two accompanying male flowers are suppressed and remained dimorphic. In a potential male primodium, the female organ is suppressed (Beirnaert, 1935). An inflorescence primordium forms in each frond axil about 36 months before it appears externally. As it emerges from the leaf axil, the inflorescences are enclosed in a woody spathe which then splits open to expose the flowers. The female flower consists of a perianth of six segments in two whorls, a tricarpellate ovary and a trifold stigma. The receptive faces of stigma lobes only open out when mature. The male flower also has six perianth parts and six stamens with four locular anthers, which contain masses of pollen. Pollinated flowers take about five to six months to mature. Fertilized flowers produce one fruit that grows and ripens in about six months (Wood, 1986).

The mature pollen grains have two cells, a generative cell and a vegetative cell (Tan, 1976). As the pollen germinates, the generative cell divides giving rise to two male gametes with chromosome complement (n), 16 (Tan, 1976). One of the gametes fertilizes the egg to form a zygote, whereas the other forms the primary endosperm nucleus. The zygote undergoes mitotic divisions to produce an embryo. One of the three ovules in the tricarpellary ovary is fertilized to produce one seed within a fruit, whereas the others degenerate. Oil formation in the endosperm and mesocarp occurs about 70 days after fertilization (Tan, 1983).