Current Applied Science and Technology e-ISSN: 2586-9396

Curr. Appl. Sci. Technol. 2025, Vol. 25 (No. 4), e0263899

Research article

Sensitivity of *Phytophthora palmivora* Causing Durian Diseases to Metalaxyl-M and Dimethomorph in Southern and Eastern Thailand

Pornprapa Kongtragoul[1]*, Sasidara Charoensiri[1], Somkiat Rimchon[2] and Susan Knight[3]

[1]*Department of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Prince of Chumphon Campus, Thailand*
[2]*Syngenta Crop Protection Company Limited, Thailand*
[3]*Syngenta Asia Pacific Pte. Ltd., Singapore*

Received: 4 July 2024, Revised: 11 December 2024, Accepted: 11 December 2024, Published:12 March 2025

Abstract

Metalaxyl-M (Met-M) and dimethomorph (Dim) are two systemic fungicides commonly used in Thailand to treat durian rot diseases caused by *Phytophthora palmivora*, a pathogen that significantly affects durian production. Fungicides have long been used by Thai durian farmers to control this infection, but managing the disease has become increasingly challenging in recent years. Monitoring fungicide resistance evolution is essential for effective disease management. In 2020 and 2022, eighty-one and sixty isolates, respectively, were collected from naturally infected durians in southern and eastern Thailand. All isolates were identified as *P. palmivora* through sporangium formation. Furthermore, 23 out of the 141 isolates were confirmed as *P. palmivora* based on sequencing of the internal transcribed spacer (ITS) and 5.8S regions of rDNA. All isolates were tested for mycelium growth sensitivity to Met-M and Dim. EC_{50} values were used to classify sensitivity into three categories: sensitive (S) at EC_{50} < 1 mgL^{-1}, moderately resistant (MR) at EC_{50} between 1 and 100 mgL^{-1}, and resistant (R) at EC_{50} > 100 mgL^{-1}. In southern Thailand, 58% of the isolates were Met-$M^{R}$$Dim^{S}$, and 41.25% were Met-$M^{S}$$Dim^{S}$. In eastern Thailand, 36.67% were Met-$M^{MR}$$Dim^{S}$, and 41.67% were Met-$M^{S}$$Dim^{S}$. These findings indicate that the populations of *P. palmivora* in the durian orchards in southern and eastern Thailand consisted of a mixture of sensitive, moderately resistant, and resistant strains.

Keywords: fungicide sensitivity; durian diseases; *Phytophthora palmivora*; metalaxyl-M; dimethomorph

1. Introduction

Durian (*Durio zibethinus* L.) is the king of tropical fruits and one of Thailand's most valuable economic fruits, commanding a high price. It can be grown in all regions of Thailand, with

*Corresponding author: E-mail: pornprapa.ko@kmitl.ac.th
https://doi.org/10.55003/cast.2025.263899

the southern and eastern regions having the most planting area. The Department of Agricultural Promotion reported that Thailand exported durians worth USD 3.219 billion in 2022, including fresh and frozen durians (Office of Agricultural Economics, 2023). Thailand has the largest durian export market, accounting for 93.3% global market share where the major markets are China, Hong Kong, and Taiwan. In this regard, Vietnam and Malaysia are significant competitors in the durian trade. However, root rot, stem rot, and fruit rot diseases caused by pathogens in the genus *Phytophthora* are key constraints in durian production. The southern and eastern parts of Thailand have high rainfall and high humidity, creating an environment that is highly conducive to outbreaks of *Phytophthora* diseases (Drenth & Guest, 2004; Suksiri et al., 2018). This pathogen can spread in air and water with rapid multiplication of inoculum-sporangia and motile zoospores. It produces chlamydospores and oospores for survival outside the host, and the disease cycle is driven by free water and high humidity (Lim & Sangchote, 2003; Drenth & Guest, 2004; Abad & Cruz, 2012). Most Thai durian farmers have used multiple chemical fungicide groups for controlling *Phytophthora* species, for example, phenylamides (metalaxyl, metalaxyl-M), phosphonates (fosetyl-Al, phosphorous acid), carboxylic acid amides (dimethomorph), or dithiocarbamates (mancozeb, maneb), and so on (Knowledge Management Team, Office of Agricultural Research and Development Region 6, 2022). Although these fungicides effectively suppress and control diseases, their long-term use may lead to reduced effectiveness due to the evolution of pathogen resistance to fungicides. Such an increase in fungicide-resistant strains in pathogen populations results in economic problems (Deising et al., 2008; Ishii & Hollomon, 2015). The issue of chemical resistance in *Phytophthora palmivora*, particularly in the context of durian cultivation, has become increasingly critical due to the widespread use of fungicides such as metalaxyl. This pathogen is responsible for significant losses in durian production, causing root and stem rot diseases that can devastate crops (Kongtragoul et al., 2021; Numba, 2023). Metalaxyl, a phenylamide fungicide, has been effective against various *Phytophthora* species; however, its overuse has led to the development of resistant strains, complicating disease management strategies (Cui et al., 2018; Kongtragoul et al., 2021). Research has shown that metalaxyl resistance in *P. palmivora* is associated with specific genetic mutations that affect the pathogen's sensitivity to the fungicide. Studies have indicated that the intrinsic risk of resistance development is high due to the site-specific action of metalaxyl, which has been documented in multiple *Phytophthora* species, including *P. nicotianae* (Cui et al., 2018). Resistance mechanisms often involve alterations in the target sites of the fungicide, leading to reduced efficacy and necessitating the exploration of alternative management strategies (Kongtragoul et al., 2021; Zhang et al., 2022). To help develop effective strategies for controlling *Phytophthora* diseases, in this research, we monitored the fungicide sensitivity of *Phytophthora* isolates from the largest durian planting areas in Thailand. We focused on metalaxyl-M and dimethomorph because most farmers use both fungicides. Both fungicides have specific target sites; metalaxyl-M inhibits fungal ribosomal RNA polymerases, while dimethomorph targets cell wall biosynthesis via cellulose synthase inhibition (Fungicide Resistance Action Committee (FRAC), 2020).

Fungicide Resistance Action Committee (FRAC) (2020) reported on field resistance to phenylamides among *Phytophthora* species, including *P. cactorum* from crown rot of strawberry, *P. capsici* from stem rot of lima bean pods, *P. cinnamomi* from root rot of avocado, *P. erythroseptica* from pink rot of potato, *P. infestans* from late blight of potato, *P. melonis* from foot rot of cucurbits, and *P. nicotianae* from root rot of ornamentals. In Thailand, metalaxyl resistance was first reported in 2011 in *P. infestans* isolates that caused late blight of potatoes in northern Thailand (Chiampiriyakul et al., 2011). Subsequently, Kongtragoul et al. (2021) reported that nine out of twenty isolates of *P.*

palmivora associated with durian diseases in southern Thailand during 2016-2017 were resistant to phenylamide fungicides. Similarly, Somnuek et al. (2023) found that 24 out of 40 *P. palmivora* isolates exhibited resistance to metalaxyl, with EC_{50} values exceeding 100 mg/L, in eastern and southern Thailand in 2023. Dimethomorph resistance has not yet been reported in Thailand. However, Tongsri et al. (2023) reported that all *P. palmivora* isolates were sensitive to dimethomorph in eastern Thailand. *Phytophthora palmivora* has been isolated from durian, but information on the resistance of *Phytophthora* spp. to fungicides, aside from phenylamides, remains limited in Thailand. There are significant knowledge gaps regarding resistance mechanisms and the potential for resistance development to dimethomorph in *P. palmivora*, which remain an underexplored area in Thailand. Monitoring of fungicide resistance is crucial for supporting sustainable durian disease management strategies.

To address the challenge of chemical resistance, integrated pest management (IPM) strategies are being recommended for durian growers. These strategies include the use of resistant cultivars, cultural practices, and biological control methods (Kongtragoul et al., 2021; Numba, 2023). For example, potassium phosphite has been suggested as an effective alternative to metalaxyl, offering a different mode of action that may help mitigate resistance issues (Zhang et al., 2022). Furthermore, the efficacy of various fungicides has been evaluated in the context of *Phytophthora* management. Studies have indicated that while metalaxyl remains one of the most effective substances for controlling *Phytophthora*, its effectiveness can vary based on environmental factors and the specific strain of the pathogen (Rosário et al., 2021). Continuous monitoring of *Phytophthora* populations and their resistance profiles is essential for the sustainable management of durian crops (Kongtragoul et al., 2021; Zhang et al., 2022). Therefore, the aims of this research were (i) to survey and collect *Phytophthora* isolates from naturally infected durians in commercial orchards under pressure of fungicide resistance in southern and eastern Thailand, (ii) to identify them based on morphological characterization and analyze their internal transcribed spacer (ITS) and 5.8S regions of rDNA to identify the species, and (iii) to evaluate the metalaxyl-M and dimethomorph sensitivity in both regions.

2. Materials and Methods

2.1 Locations

Disease samples of the fruit, branch, and stem of ‘Monthong’ durian that showed natural infection were collected in 2020 and 2022 from 10 locations in the southern region (6 locations in Chumphon, 2 locations in Surat Thani, and 2 locations in Ranong) and 10 locations in the eastern region (6 locations in Chanthaburi, 2 locations in Rayong, and 2 locations in Trat) of Thailand. Sampling did not occur in 2021 due to COVID-19 restrictions. Five to ten strains were collected per location, with sampling areas spaced approximately 2-3 km apart. Geographic details are provided in Table 1.

2.2 Isolation and identification

2.2.1 Isolation

The plant tissue from the margin between the diseased and healthy areas was cut into approximately 5 x 5 mm pieces and surface sterilized by soaking in 10% Clorox® solution

Table 1. List of durian orchards with details of each location

Year	Province	District	Sub-district	Location Code	GPS	
					Latitude	Longitude
2020	**Southern**					
	Chumphon	Mueang	Tham Sing	CL1	10° 24´ 55˝N	99°03´33˝E
		Sawi	Na Sak	CL2	10° 13´ 56˝N	99° 00´02˝E
		Thun Tako	Thung Takhrai	CL3	10° 08´ 25˝N	99° 06´26˝E
		Tha Sae	Hong Charoen	CL4	10° 48´ 36˝N	99° 06´59˝E
		Pathio	Khao Chai Rat	CL5	10° 54´ 51˝N	99° 17´04˝E
		Tha Sae	Rap Ro	CL6	10° 51´ 59˝N	99° 03´15˝E
	Suratthani	Ban Na Doem	Na Tai	SL1	08° 55´ 45˝N	99° 20´56˝E
		Mueang	Khunthale	SL2	09° 01´ 43˝N	99° 20´01˝E
	Ranong	Kra Buri	Lam Liang	RL1	10° 19´ 40˝N	98° 48´33˝E
		Kra Buri	Cho Po ro	RL2	10° 38´ 35˝N	98° 55´36˝E
	Eastern					
	Chanthaburi	Makham	Tha Luang	ChL4	12° 40´56˝N	102° 8´46˝E
	Rayong	Khao Chamao	Cham Kho	RYL1	12° 53´45˝N	101°37´52˝E
2022	**Eastern**					
	Chanthaburi	Khlung	Trok Nong	Chl1	12° 32´22 N	102°16´34 E
		Khlung	Trok Nong	Chl2	12° 31´59 N	102°15´42 E
		Na Yai Am	Wang Tanot	Chl3	12° 42´24 N	101° 57´02 E
		Na Yai Am	Wang Tanot	Chl4	12° 41´18 N	101° 55´51 E
		Na Yai Am	Sanamchai	Chl5	12° 39´51 N	101° 53´32 E
		Na Yai Am	Na Yai Am	Chl6	12° 43´58 N	101° 51´05 E
	Rayong	Klaeng	Huai Yang	RyL2	12° 48´44 N	101°32´28 E
	Trat	Mueang	Laem Klat	TrL1	12° 07´33 N	102°41´06 E
		Mueang	Laem Klat	TrL2	12° 08´14 N	102°40´38 E

for 1-2 min, rinsed with sterile distilled water, and blotted dry on sterile paper towels. The dried tissues were placed on a PAR (PH)-V8 selective medium and incubated at room temperature (RT) of approximately 28-30°C. Isolate designation: Isolates were coded using the following format: Province [C = Chumphon, S = Surat Thani, R = Ranong, Ch = Chanthaburi, Ry = Rayong, Tr = Trat], Location [L1 = Location 1, L2 = Location 2, L3 = Location 3, L4 = Location 4, L5 = Location 5, L6 = Location 6], Tissue part [S = Stem, B = Branch, F =Fruit] and **,** Isolate number [1, 2, 3, etc.]. For example: CL1_S1 represents an isolation from Chumphon, Location 1, durian stem, isolate number 1.

2.2.2 Identification

The morphological identification of the *Phytophthora* species was based on IDphy, an international online resource (https://idtools.org/id/phytophthora/results.php?terms= palmivora) and the published description (André & Sendall, 2001; Abad et al., 2023). Key characteristics for *P. palmivora* include colonies with no distinctive pattern (uniform, radial, stellate, chrysanthemum, and rosette) and sporangia that are caducous with short pedicels and variable in shape (globose, ovoid, obpyriform, ellipsoid and irregular) originated from simple sympodial sporangiophores.

The total DNA was extracted using the DNeasy®Plant Mini Kit (QIAGEN, Hilden, Germany). The extracted DNA served as template for amplification with ITS1 (5'-TCCGTAGGTGAACCTGCGG-3') and ITS4 (5'TCCTCCGCTTATTGATATGC-3') of the internal transcribed spacer (ITS) of rDNA regions using polymerase chain reaction (PCR) (White et al., 1990). The PCR products were directly sequenced using cycle sequencing with ITS1 and ITS4 primers from Axil Scientific Pte Ltd., Singapore. Sequence similarity analyses were performed using the Basic Local Alignment Search Tool (BLAST) from the National Center for Biotechnology Information (NCBI) GenBank database.

2.3 Fungicide sensitivity assay

Commercial formulations of the fungicides shown in Table 2 were used in this experiment. The fungicide sensitivity to metalaxyl-M and dimethomorph of all tested isolates was assessed by a mycelial growth assay performed on clarified V8 juice agar culture plates. After autoclaving, the medium was amended with 0, 0.1, 1, 10, and 100 mgL^{-1} (a.i.) of each fungicide. Mycelial discs, 4 mm in diameter, were cut from actively growing colony margins and transferred upside down to the plates before incubating at room temperature (28-30°C). After incubation for 3 days, the colony diameters of isolates grown on the fungicide-amended and unamended medium were recorded, and the percentage of mycelial growth inhibition by fungicides was calculated.

Table 2. Fungicides used to determine the *in vitro* sensitivity of *Phytophthora* spp. in this study

Chemical Group	Chemical Name	Distribution in Plant	Formulation Type	Active Ingredient
Phenylamides	Metalaxyl-M	Systemic	Emulsions for seed treatment (ES)	35% w/v
Carboxylic acid amides	Dimethomorph	Systemic	Suspension concentrate (SC)	50% w/v

2.4 Data analysis of fungicide sensitivity

Mycelial growth inhibition (%) values were plotted as probits versus the log10 of the fungicide concentration (mgL^{-1}) and analyzed by linear regression. The regression equation estimated the 50% effective concentration (EC_{50}) to inhibit each isolate's mycelial growth. The EC_{50} values were used to identify three categories of sensitivity to both fungicides, which were based on Peters et al. (2001) and Tian et al. (2016) as follows: sensitive (S) = EC_{50} < 1 mgL^{-1}, moderately resistant (MR) = EC_{50} 1-100 mgL^{-1}, and resistant (R) = EC_{50} > 100 mgL^{-1}.

3. Results and Discussion

3.1 Collection and isolation

Naturally infected durian fruit, branch, and stem samples that showed typical rot symptoms were collected from twenty commercial durian orchards in Thailand, including the 10 southern locations [Chumphon (n=6), Surat Thani (n=2), and Ranong (n=2)] and the 10 eastern locations [Chanthaburi (n=6), Rayong (n=2), and Trat (n=2)] in 2020 and after covid19 in 2022. All durian orchards were commercial fields that had been regularly treated with fungicides, typically applied every 7-10 days, or 2-3 times per month during the rainy season. Metalaxyl, metalaxyl-M, and dimethomorph were applied via spraying or trunk painting, often mixed with mancozeb to control *Phytophthora* diseases. Fruit rot (Figure 1a), stem rot, and branch rot (Figure 1b) samples that showed natural infection were collected from durian orchards in southern and eastern Thailand in 2020 and 2022. One hundred and forty-one isolates were successfully isolated from 10 locations in southern Thailand and 10 locations in eastern Thailand (Table 3). Eighty-one and six isolates were collected from the southern and eastern regions, respectively, in 2020. After COVID-19 in 2022, fifty-four isolates were collected from the east region. All isolates were identified as *Phytophthora palmivora* based on the colony (Figure 2a) and sporangium formation (Figure 2b). Each isolate was purified by single sporangium isolation, and the culture was preserved at 4^{o}C for further study. Out of 141 isolates randomized from each location tested (Table 4), 23 isolates were identified as *P. palmivora*. Sequences analysis of the rDNA-ITS region revealed 100% aligned at of *P. palmivora* sequence from the NCBI, except for isolates CL4_S4 and CL4_F1, which showed 97.20% and 98.88% alignment, respectively. The ITS sequences of the 23 isolates were deposited in NCBI under accession numbers OR655080 to OR655102. Multiple sequence alignment was compared with reference sequence (NCBI accession number MN750015), as illustrated in Figure 3.

The genus *Phytophthora* includes destructive pathogens that significantly impact Thai durian production. It infects many parts of durian tree, including roots, stems, branches, and fruits, and can ultimately lead to the death of the standing durian tree. In this study, we collected pathogen isolates from naturally infected ‘Monthong’ cultivars in commercial orchards across southern and eastern Thailand. All isolates were identified as *P. palmivora* based on morphological characteristics using IDphy, an international online resource, and confirmed through nucleotide sequences of the nucleotide sequences of the ITS and 5.8S regions of rDNA. Similarly, *P. palmivora* has been reported as a cause of the most destructive and economically significant disease of durian in Southeast Asia countries such as Thailand (Kongtragoul et al., 2021), Malaysia (Mohamed et al., 2019), Indonesia (Peters et al., 2001), Vietnam (Gisi et al., 1997), The Philippines (Solpot & Cumagun, 2022) and Brunei Darussalam (Sivapalan et al., 1997), as well as in other durian-producing regions like Australia (Vawdrey et al., 2005).

Figure 1. Rot symptoms of *Phytophthora* disease on fruits (a) stem and branch (b) of durian

Table 3. The number of isolates of *Phytophthora palmivora* from durian disease in each location of southern and eastern in 2020 and 2022

Year	Province	Location code	Samples			Total
			Fruits	Stem	Branch	
2020	**Southern**					
	Chumphon	CL1	-	13	-	13
		CL2	-	5	-	5
		CL3	-	10	-	10
		CL4	6	3	-	9
		CL5	13	-	-	13
		CL6	-	7	-	7
	Suratthani	SL1	-	7	1	8
		SL2	-	5	-	5
	Ranong	RL1	-	5	-	5
		RL2	-	6	-	6
		Total Southern	19	61	1	81
	Eastern					
	Chanthaburi	ChL4	-	1	-	1
	Rayong	RYL1	-	5	-	5
2022	**Eastern**					
	Chanthaburi	Chl1	-	6		6
		Chl2	6	-	-	6
		Chl3	6	-	-	6
		Chl4	6	-	-	6
		Chl5	6	-	-	6
		Chl6	6	-	-	6
	Rayong	RyL2	-	6	-	6
	Trat	TrL1	6	-	-	6
		TrL2	6	-	-	6
		Total Eastern	42	12	-	60

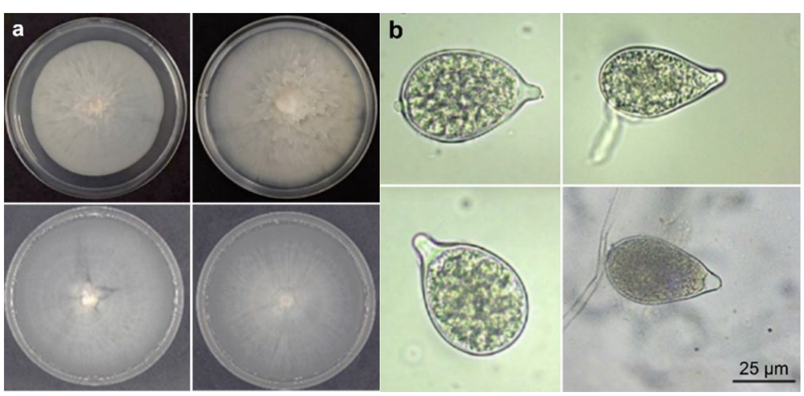

Figure 2. Colony characteristics (a) and sporangium (b) of *Phytophthora palmivora*

Table 4. *Phytophthora palmivora* responses to metalaxyl-M and dimethomorph by mycelial growth assay from southern Thailand in 2020 and eastern Thailand in 2020 and 2022

Location Code	Double Fungicide Sensitivity (no. isolate)								
	Met-M^{R} Dim^{R}	Met-M^{R} Dim^{MR}	Met-M^{R} Dim^{S}	Met-M^{MR} Dim^{R}	Met-M^{MR} Dim^{MR}	Met-M^{MR} Dim^{S}	Met-M^{S} Dim^{R}	Met-M^{S} Dim^{MR}	Met-M^{S} Dim^{S}
Southern									
CL1	-	-	12	-	-	1	-	-	-
CL2	-	-	5	-	-	-	-	-	-
CL3	-	-	2	-	-	-	-	-	8
CL4	-	-	3	-	-	-	-	-	6
CL5	-	-	2	-	-	-	-	-	11
CL6	-	-	6	-	-	-	-	-	1
SL1	-	-	3	-	-	-	-	-	5
SL2	-	-	4	-	-	-	-	-	1
RL1	-	-	5	-	-	-	-	-	-
RL2	-	-	5	-	-	-	-	-	1
Total	**-**	**-**	**47**	**-**	**-**	**1**	**0**	**-**	**33**
Eastern									
Chl1	-	-	-	-	-	6	-	-	-
Chl2	-	-	-	-	-	6	-	-	-
Chl3	-	-	-	-	-	3	-	-	3
Chl4	-	1	4	-	1	1	-	-	-
Chl5	-	-	-	-	-	2	-	-	4
Chl6	-	-	-	-	2	-	-	-	4
TrL1	-	-	-	-	-	-	-	1	5
TrL2	-	-	-	-	-	-	-	2	4
RYL1	-	-	-	-	-	-	-	-	5
RyL2	-	-	-	-	2	4	-	-	-
Total	**-**	**1**	**4**	**0**	**5**	**22**	**-**	**3**	**25**

Accession no. (isolate code)

```
OR655090   (CL4_F1)      --CTTCACGTGACCGTATCAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   58
OR655091   (CL4_S4)      --CTCACGTGACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   58
OR655082   (CL1_S2)      -------GTGACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   53
OR655100   (ChL4_S2)     -------GTGACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   53
OR655086   (CL2_S3)      ---------GACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   51
OR655096   (CL5_F12)     ------AGTGACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   54
OR655102   (RyL1_S19)    --------TGACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   52
OR655101   (RyL1_S12)    --------TGACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   52
OR655098   (RL1_S31)     --TTCACGTGACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   58
OR655083   (CL1_S5)      --------TGACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   52
OR655087   (CL2_S7)      -------CTGACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   53
OR655092   (CL4_S5)      --------TGACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   52
OR655094   (CL5_F6)      ---------TACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   51
OR655085   (CL1_S15)     ---------GACCGTATCAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   51
OR655093   (CL4_F10)     -------TGAACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   53
OR655089   (CL3_S10)     ------CTGAACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   54
OR655088   (CL3_S6)      -TTCACGTGAACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   59
OR655081   (CL5-F2)      -TTCACGTGAACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   59
MN750015                 -----CGTGAACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   55
OR655080   (CL5-F1)      CTTCACGTGAACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   60
OR655084   (CL1_S9)      -------TGAACCGTATCAAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   53
OR655095   (CL5_F11)     ---------GGACCGTATCAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   51
OR655097   (RL1_S17)     -------AGTGACCGTATCAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   53
OR655099   (RL1_S33)     ---TTCACGTGACCGTATCAAACTTAGTTGGGGGTCTCTTTCGGCGGCGGCTGCTGGCTT   57
                                     *      *****************************************
```

```
OR655090   (CL4_F1)     CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  118
OR655091   (CL4_S4)     CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  118
OR655082   (CL1_S2)     CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  113
OR655100   (ChL4_S2)    CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  113
OR655086   (CL2_S3)     CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  111
OR655096   (CL5_F12)    CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  114
OR655102   (RyL1_S19)   CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  112
OR655101   (RyL1_S12)   CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  112
OR655098   (RL1_S31)    CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  118
OR655083   (CL1_S5)     CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  112
OR655087   (CL2_S7)     CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  113
OR655092   (CL4_S5)     CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  112
OR655094   (CL5_F6)     CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  111
OR655085   (CL1_S15)    CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  111
OR655093   (CL4_F10)    CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  113
OR655089   (CL3_S10)    CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  114
OR655088   (CL3_S6)     CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  119
OR655081   (CL5-F2)     CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  119
MN750015                CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  115
OR655080   (CL5-F1)     CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  120
OR655084   (CL1_S9)     CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  113
OR655095   (CL5_F11)    CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  111
OR655097   (RL1_S17)    CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  113
OR655099   (RL1_S33)    CATTGCTGGCGGCTGCTGTTGGGAGAGCTCTATCATGGCGAGCGTTTGGGCTTCGGTCTG  117
                        ************************************************************

OR655090   (CL4_F1)     AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  178
OR655091   (CL4_S4)     AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  178
OR655082   (CL1_S2)     AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  173
OR655100   (ChL4_S2)    AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  173
OR655086   (CL2_S3)     AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  171
OR655096   (CL5_F12)    AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  174
OR655102   (RyL1_S19)   AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  172
OR655101   (RyL1_S12)   AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  172
OR655098   (RL1_S31)    AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  178
OR655083   (CL1_S5)     AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  172
OR655087   (CL2_S7)     AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  173
OR655092   (CL4_S5)     AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  172
OR655094   (CL5_F6)     AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  171
OR655085   (CL1_S15)    AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  171
OR655093   (CL4_F10)    AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  173
OR655089   (CL3_S10)    AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  174
OR655088   (CL3_S6)     AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  179
OR655081   (CL5-F2)     AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  179
MN750015                AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  175
OR655080   (CL5-F1)     AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  180
OR655084   (CL1_S9)     AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  173
OR655095   (CL5_F11)    AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  171
OR655097   (RL1_S17)    AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  173
OR655099   (RL1_S33)    AACTAGTAGCTTTTTTAAACCCATTCTTTATAACTGATTATACTGTAGGGACGAAAGTCT  177
                        ************************************************************

OR655090   (CL4_F1)     CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  238
OR655091   (CL4_S4)     CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  238
OR655082   (CL1_S2)     CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  233
OR655100   (ChL4_S2)    CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  233
OR655086   (CL2_S3)     CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  231
OR655096   (CL5_F12)    CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  234
OR655102   (RyL1_S19)   CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  232
OR655101   (RyL1_S12)   CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  232
OR655098   (RL1_S31)    CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  238
OR655083   (CL1_S5)     CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  232
OR655087   (CL2_S7)     CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  233
OR655092   (CL4_S5)     CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  232
OR655094   (CL5_F6)     CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  231
OR655085   (CL1_S15)    CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  231
OR655093   (CL4_F10)    CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  233
OR655089   (CL3_S10)    CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  234
OR655088   (CL3_S6)     CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  239
OR655081   (CL5-F2)     CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  239
MN750015                CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  235
OR655080   (CL5-F1)     CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  240
```

```
OR655084   (CL1_S9)     CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  233
OR655095   (CL5_F11)    CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  231
OR655097   (RL1_S17)    CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  233
OR655099   (RL1_S33)    CTGCTTTTAACTAGATAGCAACTTTCAGCAGTGGATGTCTAGGCTCGCACATCGATGAAG  237
                        ************************************************************

OR655090   (CL4_F1)     AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  298
OR655091   (CL4_S4)     AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGACATCTAAATTTT  298
OR655082   (CL1_S2)     AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  293
OR655100   (ChL4_S2)    AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  293
OR655086   (CL2_S3)     AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  291
OR655096   (CL5_F12)    AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  294
OR655102   (RyL1_S19)   AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  292
OR655101   (RyL1_S12)   AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  292
OR655098   (RL1_S31)    AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  298
OR655083   (CL1_S5)     AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  292
OR655087   (CL2_S7)     AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  293
OR655092   (CL4_S5)     AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  292
OR655094   (CL5_F6)     AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  291
OR655085   (CL1_S15)    AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  291
OR655093   (CL4_F10)    AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  293
OR655089   (CL3_S10)    AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  294
OR655088   (CL3_S6)     AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  299
OR655081   (CL5-F2)     AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  299
MN750015                AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  295
OR655080   (CL5-F1)     AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  300
OR655084   (CL1_S9)     AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  293
OR655095   (CL5_F11)    AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  291
OR655097   (RL1_S17)    AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  293
OR655099   (RL1_S33)    AACGCTGCGAACTGCGATACGTAATGCGAATTGCAGGATTCAGTGAGTCATCGAAATTTT  297
                        *********************************************** **** *******

OR655090   (CL4_F1)     GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  358
OR655091   (CL4_S4)     GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  358
OR655082   (CL1_S2)     GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  353
OR655100   (ChL4_S2)    GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  353
OR655086   (CL2_S3)     GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  351
OR655096   (CL5_F12)    GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  354
OR655102   (RyL1_S19)   GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  352
OR655101   (RyL1_S12)   GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  352
OR655098   (RL1_S31)    GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  358
OR655083   (CL1_S5)     GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  352
OR655087   (CL2_S7)     GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  353
OR655092   (CL4_S5)     GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  352
OR655094   (CL5_F6)     GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  351
OR655085   (CL1_S15)    GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  351
OR655093   (CL4_F10)    GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  353
OR655089   (CL3_S10)    GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  354
OR655088   (CL3_S6)     GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  359
OR655081   (CL5-F2)     GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  359
MN750015                GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  355
OR655080   (CL5-F1)     GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  360
OR655084   (CL1_S9)     GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  353
OR655095   (CL5_F11)    GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  351
OR655097   (RL1_S17)    GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  353
OR655099   (RL1_S33)    GAACGCATATTGCACTTCCGGGTTAGTCCTGGGAGTATGCCTGTATCAGTGTCCGTACAT  357
                        ************************************************************

OR655090   (CL4_F1)     CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT  418
OR655091   (CL4_S4)     CAAACTTGGTTTTCTTCCTTCCGTGCAGTCGCAGGTGGATGTGCCAGATGTGAAGTGTCT  418
OR655082   (CL1_S2)     CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT  413
OR655100   (ChL4_S2)    CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT  413
OR655086   (CL2_S3)     CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT  411
OR655096   (CL5_F12)    CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT  414
OR655102   (RyL1_S19)   CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT  412
OR655101   (RyL1_S12)   CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT  412
OR655098   (RL1_S31)    CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT  418
OR655083   (CL1_S5)     CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT  412
OR655087   (CL2_S7)     CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT  413
OR655092   (CL4_S5)     CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT  412
OR655094   (CL5_F6)     CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT  411
OR655085   (CL1_S15)    CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT  411
```

```
OR655093   (CL4_F10)     CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT   413
OR655089   (CL3_S10)     CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT   414
OR655088   (CL3_S6)      CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT   419
OR655081   (CL5-F2)      CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT   419
MN750015                 CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT   415
OR655080   (CL5-F1)      CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT   420
OR655084   (CL1_S9)      CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT   413
OR655095   (CL5_F11)     CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT   411
OR655097   (RL1_S17)     CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT   413
OR655099   (RL1_S33)     CAAACTTGGTTTTCTTCCTTCCGTGTAGTCGGTGGTGGATGTGCCAGATGTGAAGTGTCT   417
                         ************************ *****   ***************************

OR655090   (CL4_F1)      TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   478
OR655091   (CL4_S4)      TGCGGCTGGGCTTCTGATCCGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   478
OR655082   (CL1_S2)      TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   473
OR655100   (ChL4_S2)     TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   473
OR655086   (CL2_S3)      TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   471
OR655096   (CL5_F12)     TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   474
OR655102   (RyL1_S19)    TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   472
OR655101   (RyL1_S12)    TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   472
OR655098   (RL1_S31)     TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   478
OR655083   (CL1_S5)      TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   472
OR655087   (CL2_S7)      TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   473
OR655092   (CL4_S5)      TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   472
OR655094   (CL5_F6)      TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   471
OR655085   (CL1_S15)     TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   471
OR655093   (CL4_F10)     TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   473
OR655089   (CL3_S10)     TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   474
OR655088   (CL3_S6)      TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   479
OR655081   (CL5-F2)      TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   479
MN750015                 TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   475
OR655080   (CL5-F1)      TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   480
OR655084   (CL1_S9)      TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   473
OR655095   (CL5_F11)     TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   471
OR655097   (RL1_S17)     TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   473
OR655099   (RL1_S33)     TGCGGCTGGTCTTCGGATCGGCTGTGAGTCCTTTGAAATGTACTGAACTGTACTTCTCTT   477
                         ********* **** **** ****************************************

OR655090   (CL4_F1)      TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   538
OR655091   (CL4_S4)      TGCTCCAAAAGCGTGCAGTTGCTGATTGTGGAGGCTGCTTGCGTATCCAGTCTGGCGACC   538
OR655082   (CL1_S2)      TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   533
OR655100   (ChL4_S2)     TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   533
OR655086   (CL2_S3)      TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   531
OR655096   (CL5_F12)     TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   534
OR655102   (RyL1_S19)    TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   532
OR655101   (RyL1_S12)    TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   532
OR655098   (RL1_S31)     TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   538
OR655083   (CL1_S5)      TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   532
OR655087   (CL2_S7)      TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   533
OR655092   (CL4_S5)      TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   532
OR655094   (CL5_F6)      TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   531
OR655085   (CL1_S15)     TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   531
OR655093   (CL4_F10)     TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   533
OR655089   (CL3_S10)     TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   534
OR655088   (CL3_S6)      TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   539
OR655081   (CL5-F2)      TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   539
MN750015                 TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   535
OR655080   (CL5-F1)      TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   540
OR655084   (CL1_S9)      TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   533
OR655095   (CL5_F11)     TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   531
OR655097   (RL1_S17)     TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   533
OR655099   (RL1_S33)     TGCTCCAAAAGCGTGGCGTTGCTGATTGTGGAGGCTGCTTGCGTAGCCAGTCTGGCGACC   537
                         ***************  **************************** **************

OR655090   (CL4_F1)      AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC   598
OR655091   (CL4_S4)      AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCTCGGTATGGTTGGCTTCGGC   598
OR655082   (CL1_S2)      AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC   593
OR655100   (ChL4_S2)     AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC   593
OR655086   (CL2_S3)      AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC   591
OR655096   (CL5_F12)     AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC   594
OR655102   (RyL1_S19)    AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC   592
OR655101   (RyL1_S12)    AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC   592
```

```
OR655098   (RL1_S31)    AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  598
OR655083   (CL1_S5)     AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  592
OR655087   (CL2_S7)     AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  593
OR655092   (CL4_S5)     AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  592
OR655094   (CL5_F6)     AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  591
OR655085   (CL1_S15)    AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  591
OR655093   (CL4_F10)    AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  593
OR655089   (CL3_S10)    AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  594
OR655088   (CL3_S6)     AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  599
OR655081   (CL5-F2)     AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  599
MN750015                AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  595
OR655080   (CL5-F1)     AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  600
OR655084   (CL1_S9)     AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  593
OR655095   (CL5_F11)    AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  591
OR655097   (RL1_S17)    AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  593
OR655099   (RL1_S33)    AGTTTGTCTGCTGTGGCATTAATGGAGGAGTGTTCGATTCGCGGTATGGTTGGCTTCGGC  597
                        **************************************** *******************

OR655090   (CL4_F1)     TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  658
OR655091   (CL4_S4)     TGAACAGACGCTCATTAAATATATCTTCAGCTGTGGAGGGATGAGTTGGTGAACCGTAGC  658
OR655082   (CL1_S2)     TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  653
OR655100   (ChL4_S2)    TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  653
OR655086   (CL2_S3)     TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  651
OR655096   (CL5_F12)    TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  654
OR655102   (RyL1_S19)   TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  652
OR655101   (RyL1_S12)   TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  652
OR655098   (RL1_S31)    TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  658
OR655083   (CL1_S5)     TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  652
OR655087   (CL2_S7)     TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  653
OR655092   (CL4_S5)     TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  652
OR655094   (CL5_F6)     TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  651
OR655085   (CL1_S15)    TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  651
OR655093   (CL4_F10)    TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  653
OR655089   (CL3_S10)    TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  654
OR655088   (CL3_S6)     TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  659
OR655081   (CL5-F2)     TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  659
MN750015                TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  655
OR655080   (CL5-F1)     TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  660
OR655084   (CL1_S9)     TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  653
OR655095   (CL5_F11)    TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  651
OR655097   (RL1_S17)    TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  653
OR655099   (RL1_S33)    TGAACAGACGCTTATTAAATATTTCTTCAGCTGTGGTGGTATGAGTTGGTGAACCGTAGC  657
                        ************ ********* ************* ** ********************

OR655090   (CL4_F1)     TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAGTAGAGTGCG---GCTTCGCT  715
OR655091   (CL4_S4)     TATGTGAGCTTGGCTTTTGAATTGGGTTTGCTGTTGCGAAATAGAGTGGCGGCTTCGGCT  718
OR655082   (CL1_S2)     TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  713
OR655100   (ChL4_S2)    TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  713
OR655086   (CL2_S3)     TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  711
OR655096   (CL5_F12)    TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  714
OR655102   (RyL1_S19)   TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  712
OR655101   (RyL1_S12)   TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  712
OR655098   (RL1_S31)    TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  718
OR655083   (CL1_S5)     TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  712
OR655087   (CL2_S7)     TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  713
OR655092   (CL4_S5)     TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  712
OR655094   (CL5_F6)     TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  711
OR655085   (CL1_S15)    TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  711
OR655093   (CL4_F10)    TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  713
OR655089   (CL3_S10)    TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  714
OR655088   (CL3_S6)     TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  719
OR655081   (CL5-F2)     TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  719
MN750015                TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  715
OR655080   (CL5-F1)     TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  720
OR655084   (CL1_S9)     TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  713
OR655095   (CL5_F11)    TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  711
OR655097   (RL1_S17)    TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  713
OR655099   (RL1_S33)    TATGTGAGCTTGGCTTTTGAATTGGCTTTGCTGTTGCGAAGTAGAGTGGCGGCTTCGGCT  717
                        ************************* *************         *     *  ***

OR655090   (CL4_F1)     GTCGAGGGTCGATCCATTTG-GGACTTGTGTATGCTTCGGCATGCATCTCATTGGACCTG  774
OR655091   (CL4_S4)     GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCTTCATGCATCTCACTTGGACCT  778
```

```
OR655082   (CL1_S2)     GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  773
OR655100   (ChL4_S2)    GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  773
OR655086   (CL2_S3)     GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  771
OR655096   (CL5_F12)    GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  774
OR655102   (RyL1_S19)   GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  772
OR655101   (RyL1_S12)   GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  772
OR655098   (RL1_S31)    GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  778
OR655083   (CL1_S5)     GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  772
OR655087   (CL2_S7)     GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  773
OR655092   (CL4_S5)     GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  772
OR655094   (CL5_F6)     GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  771
OR655085   (CL1_S15)    GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  771
OR655093   (CL4_F10)    GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  773
OR655089   (CL3_S10)    GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  774
OR655088   (CL3_S6)     GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  779
OR655081   (CL5-F2)     GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  779
MN750015                GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  775
OR655080   (CL5-F1)     GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  780
OR655084   (CL1_S9)     GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  773
OR655095   (CL5_F11)    GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  771
OR655097   (RL1_S17)    GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  773
OR655099   (RL1_S33)    GTCGAGGGTCGATCCATTTGGGAACTTGTGTATGCTTCGGCATGCATCTCAATTGGACCT  777
                        ******************* * ***************   *********** * *  *

OR655090   (CL4_F1)     -ATATCAGC--AGATTACCCGCTGACTTAGCATATCATAGCCGGA----             816
OR655091   (CL4_S4)     GATATCAGGGAAGATTACACCCTGACCTTGATCATATA-----------             816
OR655082   (CL1_S2)     GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCATAGA------             816
OR655100   (ChL4_S2)    GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATC-----------             811
OR655086   (CL2_S3)     GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAAA-----             815
OR655096   (CL5_F12)    GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAAA-----             818
OR655102   (RyL1_S19)   GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAACGGA--             819
OR655101   (RyL1_S12)   GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAACGCGA-             820
OR655098   (RL1_S31)    GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAAC-----             822
OR655083   (CL1_S5)     GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATA-------             814
OR655087   (CL2_S7)     GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAACCC---             819
OR655092   (CL4_S5)     GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAA---------             812
OR655094   (CL5_F6)     GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAACCGGA-             819
OR655085   (CL1_S15)    GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAGG-----             815
OR655093   (CL4_F10)    GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAAAAGGGA---             819
OR655089   (CL3_S10)    GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAACCCGA-             822
OR655088   (CL3_S6)     GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAAAAACGGA--             826
OR655081   (CL5-F2)     GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAGGCCA--             826
MN750015                GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAAGC----             820
OR655080   (CL5-F1)     GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAAGCCAGA             829
OR655084   (CL1_S9)     GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAA---------             813
OR655095   (CL5_F11)    GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAGGCC---             817
OR655097   (RL1_S17)    GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAAACGGGA             822
OR655099   (RL1_S33)    GATATCAGGCAAGATTACCCGCTGAACTTAAGCATATCAATAAACGGA-             825
                        *******   ******* * ****  *     **
```

Figure 3. Multiple sequence alignments of rDNA-ITS regions in *Phytophthora palmivora* isolates analyzed in this study. The accession number and isolate code are shown in the left of the column

3.2 Fungicide sensitivity

The sensitivity of all isolates of *Phytophthora* spp. to metalaxyl-M and dimethomorph was tested. The regression equation was used to estimate the 50% effective concentration (EC_{50}) to inhibit the mycelial growth of each isolate (Table 5). As shown in Table 4, in most of the tested locations, the pathogen population consisted of a mix of isolates with more than one fungicide sensitivity profile. In southern Thailand, 47 out of 81 isolates were resistant to metalaxyl-M, with an EC_{50} of >100 mgL^{-1}. Only one isolate (CL1_S13) from CL1 was moderately resistant to metalaxyl-M with EC_{50} 3.31 mgL^{-1}. Thirty-three isolates that were sensitive to metalaxyl-M. Met-M^R strains were detected in all locations in southern

Thailand. Moreover, strains that were sensitive to both metalaxyl-M and dimethomorph were detected in all surveyed provinces of south and eastern Thailand. In the east of Thailand, 5 of 60 isolates were resistant to metalaxyl-M with an EC_{50} >100 mgL^{-1}; 27 isolates were moderately resistant to metalaxyl-M with an EC_{50} 1.15-89.93 mgL^{-1}, and 38 isolates were sensitive to metalaxyl-M. In the southern region, all isolates were sensitive to dimethomorph. In the eastern region, 9 out of 60 isolates were moderately resistant to dimethomorph with 1.07-2.71 mgL^{-1}, and 51 isolates were sensitive to dimethomorph with EC_{50} < 1 mgL^{-1} (Table 5).

Chemical fungicides are still crucial for controlling this pathogen and sustaining durian production in Thailand. Fungicides are sprayed frequently, at about 7-10-day intervals. Thus, monitoring fungicide resistance development in this pathogen is essential for guiding Thai durian farmers. These results indicate that the *P. palmivora* populations in Thailand are mainly sensitive to dimethomorph, while the population contains a mixture of metalaxyl-M-resistant, moderately resistant, and sensitive strains. However, several factors must be considered in interpreting results, such as the type of assays used and fungicide mode of action, especially in the absence of baseline sensitivity data. The results differed between the southern and eastern regions; isolates with resistance to metalaxyl-M were detected in all surveyed southern locations, while in the east region, most strains were sensitive or moderately resistant to metalaxyl-M. All strains were moderately resistant or sensitive to dimethomorph, with EC_{50} of 1-100 mgL^{-1} and EC_{50} < 1 mgL^{-1}, respectively. The detection of *P. palmivora* isolates with resistance to metalaxyl-M indicates that this fungicide might not offer effective control of *Phytophthora* diseases in durian. Previously, Kongtragoul et al. (2021) reported that in 2016-2017, *Phytophthora* spp. were resistant to metalaxyl in the same area of southern Thailand (metalaxyl is a racemic mixture, while metalaxyl-M is solely (97%) the R-enantiomer). Dimethomorph-resistant isolates of *P. palmivora* were not found in this study, although nine isolates were observed with moderate sensitivity. Dimethomorph was introduced more than 10 years ago and has been used to control durian diseases caused by *P. palmivora* without reports of resistance. On the FRAC pathogen risk list; Fungicide Resistance Action Committee (FRAC) (2022) classified the resistance risk of this fungicide as low to medium (Thanh et al., 2023). Although CAA-resistant isolates of *Plasmopara viticola* have been detected in the Europe zone, *P. infestans* is considered to have a low risk of developing such resistance.

In the durian orchards of south and eastern Thailand, phenylamides (PA) fungicides are sprayed approximately 2-4 times/month or more during the rainy season, creating a selection pressure for resistance to these fungicides. PA fungicides have been used in both regions for longer than dimethomorph, which may explain the higher number of strains with elevated metalaxyl-M EC_{50} values. The presence of strains of *P. palmivora* with moderate or high resistance to metalaxyl-M has been confirmed in southern and eastern Thailand durian orchards. We conclude that metalaxyl-M use should be considered carefully, as it could increase the management costs for durian production in Thailand if control is not fully effective. Metalaxyl-M should not be used for *Phytophthora* disease control in orchards where metalaxyl-resistant strains have already appeared and are widely distributed. However, in locations in which metalaxyl-sensitive strains are dominant, farmers should follow good resistance management practices, with the use of metalaxyl-M in disease management programs that include effective fungicides with other modes of action groups. Studies conducted over several years in *Phytophthora infestans* in European potato fields showed that during the epidemic phase of the disease cycle, the proportion of phenylamide-resistant strains increased, irrespective of whether the fields were treated with phenylamide fungicides (Abad et al., 2023). At the beginning of the next

Table 5. EC_{50} values of *Phytophthora* spp. from southern in 2020 and earthen in 2020 and 2022 in response to metalaxyl-M and dimethomorph by mycelial growth assay

No.	Isolate code	Metalaxyl-M		Dimethomorph	
		EC_{50} (mgl^{-1})	Sensitivity Type	EC_{50} (mgl^{-1})	Sensitivity Type
2020, Southern					
1	CL1_S1	>100	R	0.28	S
2	CL1_S2	>100	R	0.32	S
3	CL1_S3	>100	R	0.34	S
4	CL1_S4	>100	R	0.28	S
5	CL1_S5	>100	R	0.42	S
6	CL1_S6	>100	R	0.33	S
7	CL1_S8	>100	R	0.30	S
8	CL1_S9	>100	R	0.44	S
9	CL1_S11	>100	R	0.60	S
10	CL1_S12	>100	R	0.37	S
11	CL1_S13	3.31	MR	0.41	S
12	CL1_S14	>100	R	0.50	S
13	CL1_S15	>100	R	0.11	S
14	CL2_S1	>100	R	0.16	S
15	CL2_S2	>100	R	0.28	S
16	CL2_S3	>100	R	0.23	S
17	CL2_S5	>100	R	<0.1	S
18	CL2_S7	>100	R	0.12	S
19	CL3_S1	0.20	S	0.22	S
20	CL3_S2	<0.1	S	0.15	S
21	CL3_S3	<0.1	S	0.36	S
22	CL3_S4	<0.1	S	0.24	S
23	CL3_S5	<0.1	S	0.47	S
24	CL3_S6	<0.1	S	0.19	S
25	CL3_S7	<0.1	S	0.41	S
26	CL3_S9	<0.1	S	0.27	S
27	CL3_S10	>100	R	0.40	S
28	CL3_S11	>100	R	0.35	S
29	CL4_F1	<0.1	S	0.39	S
30	CL4_F2	<0.1	S	0.33	S
31	CL4_S3	>100	R	0.39	S
32	CL4_S4	>100	R	0.32	S
33	CL4_S5	>100	R	0.88	S
34	CL4_F7	<0.1	S	0.31	S
35	CL4_F8	<0.1	S	0.30	S
36	CL4_F9	<0.1	S	0.51	S
37	CL4_F10	<0.1	S	0.35	S
38	CL5_F1	<0.1	S	0.35	S
39	CL5_F2	<0.1	S	0.35	S
40	CL5_F3	<0.1	S	0.26	S
41	CL5_F4	<0.1	S	0.22	S
42	CL5_F5	<0.1	S	0.25	S
43	CL5_F6	<0.1	S	0.21	S
44	CL5_F7	<0.1	S	0.38	S
45	CL5_F8	<0.1	S	0.51	S
46	CL5_F9	<0.1	S	0.54	S
47	CL5_F10	<0.1	S	0.46	S
48	CL5_F11	>100	R	0.58	S
49	CL5_F12	>100	R	0.33	S

Table 5. EC_{50} values of *Phytophthora* spp. from southern in 2020 and earthen in 2020 and 2022 in response to metalaxyl-M and dimethomorph by mycelial growth assay (continued)

No.	Isolate code	Metalaxyl-M		Dimethomorph	
		EC_{50} (mgl^{-1})	Sensitivity Type	EC_{50} (mgl^{-1})	Sensitivity Type
50	CL5_F13	<0.1	S	0.32	S
51	CL6_S3	<0.1	S	<0.1	S
52	CL6_S51	>100	R	<0.1	S
53	CL6_S52	>100	R	<0.1	S
54	CL6_S53	>100	R	<0.1	S
55	CL6_S59	>100	R	<0.1	S
56	CL6_S60	>100	R	<0.1	S
57	CL6_S61	>100	R	<0.1	S
58	SL1_S4	>100	R	0.23	S
59	SL1_S6	>100	R	0.28	S
60	SL1_S8	>100	R	0.30	S
61	SL1_S20	0.66	S	0.23	S
62	SL1_S27	<0.1	S	0.15	S
63	SL1_S29	<0.1	S	<0.1	S
64	SL1_S30	<0.1	S	<0.1	S
65	SL1_B101	<0.1	S	0.28	S
66	SL2_ S2	>100	R	0.41	S
67	SL2_ S5	>100	R	0.23	S
68	SL2_S7	<0.1	S	0.32	S
69	SL2_ S8	>100	R	<0.1	S
70	SL2_S18	>100	R	<0.1	S
71	RL1_S16	>100	R	0.57	S
72	RL1_S17	>100	R	0.75	S
73	RL1_S30	>100	R	0.55	S
74	RL1_S31	>100	R	0.37	S
75	RL1_S33	>100	R	<0.1	S
76	RL2_S1	<0.1	S	<0.1	S
77	RL2_S2	>100	R	<0.1	S
78	RL2_S4	>100	R	<0.1	S
79	RL2_S5	>100	R	<0.1	S
80	RL2_S10	>100	R	<0.1	S
81	RL2_S15	>100	R	<0.1	S
2020, Eastern					
1	ChL4_S2	36.6	MR	0.41	S
2	RYL1_S12	<0.1	S	<0.1	S
3	RYL1_S18	0.10	S	0.54	S
4	RYL1_S19	<0.1	S	0.16	S
5	RYL1_S20	<0.1	S	0.16	S
6	RYL1_S30	0.17	S	0.72	S
2022, Eastern					
1	Chl1_S1	2.89	MR	<0.10	S
2	Chl1_S2	3.65	MR	<0.10	S
3	Chl1_S3	2.19	MR	<0.10	S
4	Chl1_S4	2.00	MR	<0.10	S
5	Chl1_S5	1.46	MR	<0.10	S
6	Chl1_S6	1.21	MR	<0.10	S
7	Chl2_F1	4.45	MR	0.60	S

Table 5. EC_{50} values of *Phytophthora* spp. from southern in 2020 and earthen in 2020 and 2022 in response to metalaxyl-M and dimethomorph by mycelial growth assay (continued)

No.	Isolate code	Metalaxyl-M		Dimethomorph	
		EC_{50} (mgl^{-1})	Sensitivity Type	EC_{50} (mgl^{-1})	Sensitivity Type
8	Chl2_F2	5.69	MR	0.60	S
9	Chl2_F3	4.85	MR	0.38	S
10	Chl2_F4	6.49	MR	0.25	S
11	Chl2_F5	2.73	MR	0.14	S
12	Chl2_F6	2.34	MR	0.90	S
13	Chl3_F1	3.88	MR	0.42	S
14	Chl3_F2	3.19	MR	0.39	S
15	Chl3_F3	0.64	S	0.40	S
16	Chl3_F4	1.15	MR	0.48	S
17	Chl3_F5	0.85	S	0.25	S
18	Chl3_F6	0.67	S	0.55	S
19	Chl4_F1	>100	R	0.87	S
20	Chl4_F2	89.93	MR	1.38	MR
21	Chl4_F3	>100	R	0.83	S
22	Chl4_F4	>100	R	0.96	S
23	Chl4_F5	>100	R	1.15	MR
24	Chl4_F6	>100	R	0.77	S
25	Chl5_F1	0.55	S	0.66	S
26	Chl5_F2	2.30	MR	0.88	S
27	Chl5_F3	0.64	S	0.63	S
28	Chl5_F4	<0.1	S	<0.10	S
29	Chl5_F5	0.99	S	0.94	S
30	Chl5_F6	2.09	MR	0.86	S
31	Chl6_F1	0.20	S	<0.10	S
32	Chl6_F2	<0.10	S	<0.10	S
33	Chl6_F3	2.06	MR	1.67	MR
34	Chl6_F4	2.99	MR	1.99	MR
35	Chl6_F5	<0.10	S	<0.10	S
36	Chl6_F6	<0.10	S	<0.10	S
37	TrL1_F1	0.57	S	0.24	S
38	TrL1_F2	0.84	S	1.19	MR
39	TrL1_F3	0.22	S	0.35	S
40	TrL1_F4	0.35	S	0.43	S
41	TrL1_F5	0.67	S	0.35	S
42	TrL1_F6	0.54	S	0.37	S
43	TrL2_F1	0.87	S	0.84	S
44	TrL2_F2	0.94	S	0.86	S
45	TrL2_F3	0.93	S	0.99	S
46	TrL2_F4	0.93	S	1.07	MR
47	TrL2_F5	0.88	S	1.40	MR
48	TrL2_F6	0.84	S	0.90	S
49	RyL2_S1	1.28	MR	0.96	S
50	RyL2_S2	1.50	MR	0.94	S
51	RyL2_S3	1.20	MR	0.92	S
52	RyL2_S4	1.50	MR	0.95	S
53	RyL2_S5	2.98	MR	2.71	MR
54	RyL2_S6	2.08	MR	1.75	MR

season, the proportion of phenylamine-resistant strains declined. These observations suggest that resistant isolates have a higher fitness during the epidemic phase but survive less well between seasons. Based on these findings, and considering the high systemicity of phenylamide fungicides, the FRAC recommends that they are applied in the early season or during the period of active growth of the crop for best efficacy. Although population dynamics have not been studied as extensively in other *Phytophthora* species, sensitivity monitoring has often revealed a mixture of resistant, intermediate, and sensitive strains. In such scenarios, metalaxyl-M would still be expected to provide significant fungicidal efficacy by controlling the sensitive or intermediate strains.

In contrast, populations of *P. palmivora* are still sensitive to dimethomorph, which suggests that the fungicides would give good efficacy in the surveyed areas for the time being. However, durian growers should use dimethomorph in mixture or alternation with fungicides from other mode of action groups in an integrated disease management program because the occurrence of moderately resistant strains to dimethomorph also provides an early warning of the risk of resistance development. Further studies are necessary to monitor fungicide resistance in a broader range of pathogen populations in Thailand.

4. Conclusions

A total of 141 *Phytophthora* isolates were isolated from symptomatic tissue of root, stem, and root rot of durian diseases from twenty orchards in southern and eastern Thailand. The pathogens were identified by morphology and nucleotide sequences as *P. palmivora*. Our findings confirmed the emerging fungicide resistance in populations of *P. palmivora* in both regions. The resistance to metalaxyl-M occurred in both the southern and eastern regions. All southern isolates were sensitive (S) to dimethomorph. However, MR and S isolates to dimethomorph were found in the eastern region.

5. Acknowledgements

The authors sincerely thank King Mongkut's Institute of Technology Ladkrabang, Prince of Chumphon Campus, and Syngenta Crop Protection Company Limited for supporting this study.

6. Author Contributions

Conceptualization: P.K., S.R. and S.K.; Methodology: P.K., S.R., and S.K.; Software: P.K.; validation, P.K., S.R., and S.K.; Formal analysis: P.K., S.R., and S.K..; Investigation: P.K., S.R., and S.K.; P.K., S.R., and S.K..; Data curation: P.K., S.R., and S.K.; Writing—original draft preparation: P.K.; Writing—review: P.K.; Editing: S.R. and S.K.; Visualization: S.K.; Supervision: S.K.; Project administration: P.K.; Funding acquisition: P.K., S.R. and S.K. All authors have read and agreed to the published version of the manuscript.

7. Conflicts of Interest

The authors declare no conflict of interest.

ORCID

Pornprapa Kongtragoul https://orcid.org/0000-0001-6831-0572

References

Abad, R. G., & Cruz, K. J. T. (2012). Incidence of Phytophthora fruit rot on four durian cultivars in Davao City, Philippines. *Banwa,* 9(1&2), 1-9.

Abad, Z. G., Burgess, T. I., Redford, A. J., Bienapfl, J. C., Srivastava, S., Mathew, R., & Jennings, K. (2023). *IDphy*: An international online resource for molecular and morphological identification of *Phytophthora*. *Plant Disease,* 107(4), 987-998. https://doi.org/10.1094/PDIS-02-22-0448-FE

André, D., & Sendall, B. (2001). *Practical guide to detection and identification of Phytophthora*. CRC for Tropical Plant Protection Indooroopilly Research Centre.

Chiampiriyakul, P., Sopee, J., & Mekmok, T. (2011). Evaluation of metalaxyl sensitivity among *Phytophthora infestans* by poisoned food technique using corn agar. In *Proceedings of the 49th Kasetsart University annual conference* (Vol. 1, pp. 480-487). Kasetsart University.

Cui, L., Gao, P., Guo, J., Kang, Y., & Hu, Y. (2018). Mating type and sensitivity of *Phytophthora nicotianae* from tobacco to metalaxyl and dimethomorph in Henan province, China. *Journal of Phytopathology,* 166(9), 648-653. https://doi.org/10.1111/jph.12727

Deising, H. B., Reimann, S., & Pascholati, S. F. (2008). Mechanisms and significance of fungicide resistance. *International Brazilian Journal of Microbiology,* 39(2), 286-295. https://doi.org/10.1590/S1517-83822008000200017

Drenth, A., & Guest, D. I. (2004). Principles of Phytophthora disease management. In A. Drenth & D. I. Guest (Eds.), *Diversity and management of Phytophthora in Southeast Asia* (pp. 154-160). BPA Print Group Pty Ltd.

Fungicide Resistance Action Committee (FRAC). (2020). List of first confirmed cases of plant pathogenic organisms resistant to disease control agents. https://www.frac.info/knowledge-database/downloads

Fungicide Resistance Action Committee (FRAC). (2022). *Pathogen risk list*. https://www.jcpa.or.jp/assets/file/labo/mechanism/2022/frac_code_list_2022.pdf

Gisi, U., Hermann, D., Ohl, L., & Steden, C. (1997). Sensitivity profiles of *Mycosphaerella graminicola* and *Phytophthora infestans* populations to different classes of fungicides. *International Journal of Pesticide Science,* 51(3), 290-298. https://doi.org/10.1002/(SICI)1096-9063(199711)51:3<290::AID-PS637>3.0.CO;2-H

Ishii, H., & Hollomon, D. W. (2015). *Fungicide resistance in plant pathogens: Principles and a guide to practical management*. Springer. https://doi.org/10.1007/978-4-431-55642-8

Knowledge Management Team, Office of Agricultural Research and Development Region 6. (2022). *Integrated technology for managing root rot and stem rot in durian in Eastern Thailand*. (In Thai). https://oaezone.oae.go.th/view/22/Home/EN-US

Kongtragoul, P., Ishikawa, K., & Ishii, H. (2021). Metalaxyl resistance of *Phytophthora palmivora* causing durian diseases in Thailand. *Horticulturae,* 7(10), Article 375. https://doi.org/10.3390/horticulturae7100375

Lim, T. K., & Sangchote, S. (2003). *Diseases of tropical fruit crops*. Tropical Research and Education Center, University of Florida.

Mohamed Azni, I. N. A., Sundram, S., & Ramachandran, V. (2019). Pathogenicity of Malaysian *Phytophthora palmivora* on cocoa, durian, rubber, and oil palm determines the threat of bud rot disease. *Journal of General Forest Pathology,* 49(6), Article e12557. https://doi.org/10.1111/efp.12557

Numba, S. (2023). Genetic diversity and its association with *Phytophthora palmivora* resistance in durian (*Durio zibethinus*) using RAPD markers. *Biodiversitas Journal of Biological Diversity,* 24(8), 4542-4548. https://doi.org/10.13057/biodiv/d240835

Office of Agricultural Economics. (2023). *Agricultural statistics of Thailand 2022*. Ministry of Agriculture and Cooperatives. https://www.oae.go.th/assets/portals/1/files/jounal/2566/yearbook2565.pdf

Peters, R. D., Sturz, A. V., Matheson, B. G., Arsenault, W. J., & Malone, A. (2001). Metalaxyl sensitivity of isolates of *Phytophthora erythroseptica* in Prince Edward Island. *International Journal of Plant Pathology,* 50(3), 302-309. https://doi.org/10.1046/j.1365-3059.2001.00566.x

Rosário, J. N., Coelho, V., Rodrigues, M. Â., Raimundo, S., Afonso, S., Arrobas, M., & Gouveia, M. E. (2021). Metalaxyl-M, phosphorous acid and potassium silicate applied as soil drenches show different chestnut seedling performance and protection against phytophthora root rot. *European Journal of Plant Pathology,* 161(1), 147-159. https://doi.org/10.1007/s10658-021-02309-5

Sivapalan, A., Hamdan, F. Hj., & Junaidy, M. A. H. M. (1997). Patch canker of *Durio zibethinus* caused by *Phytophthora palmivora* in Brunei Darussalam. *International Journal of Plant Disease,* 81(1), Article 113. https://doi.org/10.1094/PDIS.1997.81.1.113C

Solpot, T. C., & Cumagun, C. J. R. (2022). Phylogenetic analyses and cross-infection studies of *Phytophthora* species infecting cacao and durian in South-Central Mindanao, Philippines. *Journal of Phytopathology,* 170(1), 41-56. https://doi.org/10.1111/jph.13054

Somnuek, S., Kongtragoul, P., & Jaenaksorn, T. (2023). Fungicide resistance of *Phytophthora palmivora* causing durian diseases in Eastern and Southern Thailand and the *in vitro* alternative control by cajeput leaf extracts. *International Journal of Agricultural Technology,* 19(2), 703-720.

Suksiri, S., Laipasu, P., Soytong, K., & Poeaim, S. (2018). Isolation and identification of *Phytophthora* sp. and *Pythium* sp. from durian orchard in Chumphon province, Thailand. *International Journal of Agricultural Technology,* 14(3), 389-402.

Thanh, N. H., Thao, T. L. N., & Chon, N. M. (2023). Morphological and molecular examination of *Phytophthora* sp. to identify the causal agent of patch canker in durian (*Durio zibethinus* Murr.) in Can Tho city. *International Journal of Agricultural Technology,* 19(5), 2309-2324.

Tian, M., Zhao, L., Li, S., Huang, J., Sui, Z., Wen, J., & Li, Y. (2016). Pathotypes and metalaxyl sensitivity of *Phytophthora sojae* and their distribution in Heilongjiang, China 2011-2015. *Journal of General Plant Pathology,* 82(3), 132-141. https://doi.org/10.1007/s10327-016-0654-y

Tongsri, V., Nianwichai, P., Sichai, K., Songkumarn, P., Suttiviriya, P., & Kongtragoul, P. (2023). Sensitivity tests of dimethomorph, ethaboxam, and etridiazole on *Phytophthora palmivora* causing stem rot and leaf blight of durian in Eastern Thailand. *Agriculture and Natural Resources,* 57(4), 559-568. https://doi.org/10.34044/j.anres.2023.57.4.01

Vawdrey, L. L., Langdon, P., & Martin, T. (2005). Incidence and pathogenicity of *Phytophthora palmivora* and *Pythium vexans* associated with durian decline in far northern Queensland. *Journal of Australasian Plant Pathology,* 34, 127-128. https://doi.org/10.1071/AP04093

White, T. J., Bruns, T., Lee, S., & Taylor, J. (1990). *PCR: A guide to methods and applications*. Academic Press.

Zhang, S., Cai, J., Xie, Y., Zhang, X., Yang, X., Lin, S., Xiang, W., & Zhang, J. (2022). Anti-Phytophthora activity of halofuginone and the corresponding mode of action. *Journal of Agricultural and Food Chemistry*, 70(39), 12364-12371. https://doi.org/10.1021/acs.jafc.2c04266