

## LIST OF CONTENTS

|   | <b>Page</b> |
|---|-------------|
| Acknowledgements                                  | iii         |
| Abstract (English)                                | v           |
| Abstract (Thai)                                   | viii        |
| List of tables                                    | xii         |
| List of figures                                   | xiii        |
| Chapter 1 General introduction and Thesis outline | 1           |
| Chapter 2 Literature review                       | 5           |
| Chapter 3 Materials and Methods                   | 38          |
| Chapter 4 Results and Discussion                  | 47          |
| Chapter 5 General Discussion and Conclusion       | 162         |
| References  | 166         |
| Appendices  | 175         |
| Curriculum Vitae                                  | 176         |
| Publications                                      | 179         |

### LIST OF TABLES

| Table  | Page |
|--|------|
| 1 Summary of revised patterns of conidial germination  | 21   |
| 2 The current systematics and taxonomy of the powdery mildews  | 31   |
| 3 A primer nest of ribosomal DNA regions used for PCR on powdery mildew fungi in Tribe Phyllactinieae  | 41   |
| 4 Isolates of Phyllactinieae included for sequence analysis  | 44   |
| 5 Isolates of Phyllactinieae from Thailand included for sequence analysis and morphological comparison | 49   |
| 6 Morphological characteristics of powdery mildew on chilli species                                    | 70   |

## LIST OF FIGURES

| Figure   | Page |
|--|------|
| 1 Generalized life cycle of powdery mildews                                      | 7    |
| 2 Illustration of mycelium types   | 9    |
| 3 Appressorium type of powdery mildews   | 11   |
| 4 Representation of haustorium types   | 12   |
| 5 Haustorium of <i>Blumeria graminis</i> with a digitate appearance              | 12   |
| 6 Conidiophores  | 14   |
| 7 Conidiophore types   | 15   |
| 8 Conidial shapes of the Erysiphaceae  | 18   |
| 9 Conidial germination types   | 20   |
| 10 Microidium type pattern of conidial germination on<br><i>Phyllanthus</i> spp. | 20   |
| 11 Comparison of conidial germination types in powdery mildews                   | 23   |
| 12 Illustration of appendage types   | 25   |
| 13 Ascus types   | 26   |
| 14 Shape of ascospores   | 27   |
| 15 <i>Leveillula taurica</i>   | 33   |
| 16 <i>Phyllactinia robiniae</i>  | 34   |
| 17 <i>Pleochaeta robiniae</i>  | 35   |
| 18 <i>Pleochaeta shiraiana</i>   | 36   |
| 19 <i>Queirozia turbinate</i>  | 37   |
| 20 Primer sets for amplify nuclear ribosomal DNA (rDNA)                          | 40   |
| 21 The proportion of powdery mildew fungi found in this study                    | 48   |

## LIST OF FIGURES (CONTINUED)

| Figure |   | Page |
|--------|---|------|
| 22     | The percentage of Phyllactinieae genera found in this study                                   | 48   |
| 23     | <i>Oidiopsis</i> sp. on <i>Capsicum annuum</i> var. <i>grossum</i>                            | 54   |
| 24     | Line drawing of <i>Oidiopsis</i> sp. on <i>Capsicum annuum</i> var. <i>grossum</i>            | 55   |
| 25     | <i>Oidiopsis</i> sp. on <i>Capsicum annuum</i> var. <i>minimum</i>                            | 57   |
| 26     | Line drawing of <i>Oidiopsis</i> sp. on <i>Capsicum annuum</i> var. <i>minimum</i>            | 58   |
| 27     | <i>Oidiopsis</i> sp. on <i>Capsicum frutescens</i>  | 60   |
| 28     | Line drawing of <i>Oidiopsis</i> sp. on <i>Capsicum frutescens</i>                            | 61   |
| 29     | <i>Oidiopsis</i> sp. on <i>Capsicum frutescens</i> × <i>Capsicum chinense</i>                 | 62   |
| 30     | Line drawing of <i>Oidiopsis</i> sp. on <i>Capsicum frutescens</i> × <i>Capsicum chinense</i> | 63   |
| 31     | <i>Oidiopsis</i> sp. on <i>Capsicum</i> spp. (darby chilli)                                   | 65   |
| 32     | Line drawing of <i>Oidiopsis</i> sp. on <i>Capsicum</i> spp. (darby chilli)                   | 66   |
| 33     | <i>Oidiopsis</i> sp. on <i>Capsicum</i> spp. (maxican chilli)                                 | 67   |
| 34     | Line drawing of <i>Oidiopsis</i> sp. on <i>Capsicum</i> spp. (maxican chilli)                 | 68   |
| 35     | <i>Oidiopsis</i> sp. on <i>Euphorbia heterophylla</i>   | 72   |
| 36     | Line drawing of <i>Oidiopsis</i> sp. on <i>Euphorbia heterophylla</i>                         | 73   |
| 37     | <i>Oidiopsis</i> sp. on <i>Euphorbia pulcherrima</i>  | 75   |
| 38     | Line drawing of <i>Oidiopsis</i> sp. on <i>Euphorbia pulcherrima</i>                          | 76   |
| 39     | <i>Oidiopsis</i> sp. on <i>Galphimia glauca</i>   | 78   |
| 40     | Line drawing of <i>Oidiopsis</i> sp. on <i>Galphimia glauca</i>                               | 79   |
| 41     | <i>Oidiopsis</i> sp. on <i>Oxalis triangularis</i>  | 81   |

## LIST OF FIGURES (CONTINUED)

| Figure |   | Page |
|--------|---|------|
| 42     | Line drawing of <i>Oidiopsis</i> sp. on <i>Oxalis triangularis</i>                        | 82   |
| 43     | <i>Oidiopsis</i> sp. on <i>Sesamum indicum</i>  | 84   |
| 44     | Line drawing of <i>Oidiopsis</i> sp. on <i>Sesamum indicum</i>                            | 85   |
| 45     | <i>Oidiopsis</i> sp. on <i>Solanum aculeatissimum</i>                                     | 87   |
| 46     | Line drawing of <i>Oidiopsis</i> sp. on <i>Solanum aculeatissimum</i>                     | 88   |
| 47     | <i>Oidiopsis</i> sp. on <i>Solanum torvum</i>   | 90   |
| 48     | Line drawing of <i>Oidiopsis</i> sp. on <i>Solanum torvum</i>                             | 91   |
| 49     | <i>Ovulariopsis</i> sp. on <i>Alangium kurzii</i>   | 93   |
| 50     | Line drawing of <i>Ovulariopsis</i> sp. on <i>Alangium kurzii</i>                         | 94   |
| 51     | <i>Ovulariopsis</i> sp. on <i>Boehmeria siamensis</i>                                     | 96   |
| 52     | Line drawing of <i>Ovulariopsis</i> sp. on <i>Boehmeria siamensis</i>                     | 97   |
| 53     | Powdery mildew infected with <i>Phyllactinia</i> sp. on <i>Boehmeria siamensis</i> leaves | 98   |
| 54     | Line drawing of <i>Phyllactinia</i> sp. teleomorph on <i>Boehmeria siamensis</i>          | 98   |
| 55     | <i>Ovulariopsis</i> sp. on <i>Broussonetia papyrifera</i>                                 | 100  |
| 56     | Line drawing of <i>Ovulariopsis</i> sp. on <i>Broussonetia papyrifera</i>                 | 101  |
| 57     | Symptoms of <i>Phyllactinia cassiae-fistulae</i> on <i>Cassia fistula</i> leaves          | 104  |
| 58     | Chasmothecia produced on the lower side of <i>Cassia fistula</i> leaves                   | 104  |
| 59     | <i>Ovulariopsis</i> anamorph of <i>Phyllactinia cassiae-fistulae</i>                      | 105  |
| 60     | Line drawing of <i>Ovulariopsis</i> anamorph of <i>Phyllactinia cassiae-fistulae</i>      | 106  |
| 61     | Teleomorph of <i>Phyllactinia cassiae-fistulae</i> on <i>Cassia fistula</i>               | 107  |

### LIST OF FIGURES (CONTINUED)

| Figure |  | Page |
|--------|--|------|
| 62     | Line drawing of <i>Phyllactinia cassiae-fistulae</i> teleomorph on <i>Cassia fistula</i>           | 108  |
| 63     | <i>Ovulariopsis</i> sp. on <i>Dalbergia cana</i>   | 111  |
| 64     | Line drawing of <i>Ovulariopsis</i> sp. on <i>Dalbergia cana</i>                                   | 112  |
| 65     | <i>Phyllactinia</i> sp. on <i>Dalbergia cana</i>   | 113  |
| 66     | Line drawing of <i>Phyllactinia</i> sp. on <i>Dalbergia cana</i>                                   | 114  |
| 67     | Powdery mildew infected with <i>Phyllactinia dalbergiae</i> on <i>Dalbergia lanceolaria</i> leaves | 116  |
| 68     | <i>Ovulariopsis</i> anamorph of <i>Phyllactinia dalbergiae</i>                                     | 117  |
| 69     | Line drawing of <i>Ovulariopsis</i> anamorph of <i>Phyllactinia dalbergiae</i>                     | 118  |
| 70     | <i>Phyllactinia dalbergiae</i> on <i>Dalbergia lanceolaria</i>                                     | 119  |
| 71     | Line drawing of <i>Phyllactinia dalbergiae</i> on <i>Dalbergia lanceolaria</i>                     | 120  |
| 72     | <i>Ovulariopsis</i> sp. on <i>Ehretia laevis</i>   | 122  |
| 73     | Line drawing of <i>Ovulariopsis</i> sp. on <i>Ehretia laevis</i>                                   | 123  |
| 74     | <i>Ovulariopsis</i> sp. on <i>Euphorbia heterophylla</i>   | 125  |
| 75     | Line drawing of <i>Ovulariopsis</i> sp. on <i>Euphorbia heterophylla</i>                           | 126  |
| 76     | <i>Ovulariopsis</i> sp. on <i>Gmelina arborea</i>  | 128  |
| 77     | Line drawing of <i>Ovulariopsis</i> sp. on <i>Gmelina arborea</i>                                  | 129  |
| 78     | <i>Phyllactinia</i> sp. on <i>Gmelina arborea</i>  | 130  |
| 79     | Line drawing of <i>Phyllactinia</i> sp. on <i>Gmelina arborea</i>                                  | 131  |
| 80     | <i>Ovulariopsis</i> sp. on <i>Lagerstroma macrocarpa</i>   | 133  |
| 81     | Line drawing of <i>Ovulariopsis</i> sp. on <i>Lagerstroma macrocarpa</i>                           | 134  |

## LIST OF FIGURES (CONTINUED)

| Figure |  | Page |
|--------|--|------|
| 82     | <i>Ovulariopsis</i> sp. on <i>Morus alba</i>   | 136  |
| 83     | Line drawing of <i>Ovulariopsis</i> sp. on <i>Morus alba</i>   | 137  |
| 84     | <i>Phyllactinia</i> sp. on <i>Morus alba</i>   | 138  |
| 85     | Line drawing of <i>Phyllactinia</i> sp. on <i>Morus alba</i>   | 139  |
| 86     | <i>Ovulariopsis</i> sp. on <i>Pyrus pyrifolia</i>  | 141  |
| 87     | Line drawing of <i>Ovulariopsis</i> sp. on <i>Pyrus pyrifolia</i>  | 142  |
| 88     | <i>Ovulariopsis</i> sp. on <i>Senna siamea</i>   | 145  |
| 89     | Line drawing of <i>Ovulariopsis</i> sp. on <i>Senna siamea</i>   | 146  |
| 90     | <i>Ovulariopsis</i> sp. on <i>Terminalia bellirica</i>   | 148  |
| 91     | Line drawing of <i>Ovulariopsis</i> sp. on <i>Terminalia bellirica</i>   | 149  |
| 92     | Close-up of chasmothecia of <i>Phyllactinia</i> sp. on <i>Terminalia bellirica</i>   | 150  |
| 93     | Line drawing of <i>Phyllactinia</i> sp. on <i>Terminalia bellirica</i>   | 150  |
| 94     | A Parsimony ratchet tree which combined dataset of ITS and 28S rDNA was found using a heuristic search employing a parsimony ratchet algorithm.                              | 152  |
| 95     | Maximum parsimony tree estimated under the highest likelihood value for 25 specimens belonging to group 1 of <i>Phyllactinia</i> .   | 154  |
| 96     | Maximum parsimony tree estimated under the highest likelihood value for 28 specimens belonging to group 2 and 3 of <i>Leveillula</i> and <i>Phyllactinia</i> , respectively. | 154  |

### LIST OF FIGURES (CONTINUED)

| Figure |  | Page |
|--------|--|------|
| 97     | Maximum parsimony tree estimated under the highest likelihood value for 28 specimens belonging to group 2 and 3 of <i>Leveillula</i> and <i>Phyllactinia</i> , respectively.   | 155  |
| 98     | The Maximum parsimony phylogenetic tree of <i>Leveillula</i> sp. based on fungal ITS gene sequences. Numbers above or below branches indicate bootstrap values (>50%) from 1,000 replicates. Asterisk is represented as <i>Oidiopsis</i> that causing powdery mildew on chilli plants  | 158  |
| 99     | Phylogenetic relationship between <i>Phyllactinia dalbergiae</i> on <i>Dalbergia lanceolaria</i> , <i>P. cassiae-fistulae</i> on <i>Cassia fistula</i> , <i>Senna siamea</i> , <i>Phyllactinia</i> species and <i>Leveillula taurica</i> , inferred by parsimony ratchet method using the combined dataset of the rDNA ITS regions | 161  |