

TABLE OF CONTENTS

	Page
Acknowledgement	iii
Abstract (English)	v
Abstract (Thai)	ix
Table of Contents	xiii
List of Tables	xv
List of Figures	xxi
List of Proceeding and Publications	xxviii
Chapter 1 Introduction	1
Chapter 2 Literature Review	7
Chapter 3 Collection and Selection of Efficient Nematophagous Fungi Against Root-knot Nematode	42
Chapter 4 Classification of Nematophagous Fungi using Morphology Characteristics and Molecular Techniques	63
Chapter 5 Study on Physiological Factors and Antagonistic Potential Related to Growth and Sporulation of Nematophagous Fungi	93

Chapter 6	Biomass Culture Preparation of Competent Nematophagous Fungi for Controlling Root-knot Nematodes	152
Chapter 7	Control of Root-knot Nematodes by Biological Agent (Nematophagous Fungi) in Greenhouse and Field Experiments	175
Chapter 8	Conclusion	218
References		223
Appendices		244
Curriculum Vitae		279
Proceeding and Publications		281

LIST OF TABLES

Table		Page
2.1	Summary of Plant Parasitic Nematode Feeding Strategies	15
2.2	The most susceptible crops of root-knot nematodes	26
2.3	Typical infection structures of some nematophagous fungi	32
3.1	Number of soil samples/area required	44
3.2	List of soil samplings and their items from infected root-knot nematode plantations and areas rich in organic matter	48
3.3	List of nematophagous fungi isolating from soil plantations	52
3.4	Percentage of nematophagous fungi to kill root-knot nematodes	57
4.1	Colony characterization of eight nematophagous fungi	73
4.2	Conidiophore and conidium measurements of nematophagous fungi	74
4.3	The blast result of rDNA ITS sequences from nematophagous fungi and their closely related sequences in GenBank during June 2012	85
4.4	ITS sequence used in phylogenic analyses from GenBank	87
5.1	Effect of six media on growth of nematophagous fungi at 3, 5, 7 and 10 days after incubation	104

LIST OF TABLES (CONTINUED)

Table		Page
5.2	Effect of six media on sporulation of nematophagous fungi at 10 days after incubation	105
5.3	Effect of five temperatures on growth of nematophagous fungi at 3, 5, 7 and 10 days after incubation	109
5.4	Effect of five temperatures on sporulation of nematophagous fungi at 10 days after incubation	110
5.5	Effect of four light regimes on growth of nematophagous fungi at 3, 5, 7 and 10 days after incubation	114
5.6	Effect of four different light regimes on sporulation of nematophagous fungi at 10 days after incubation	115
5.7	Effect of pH on growth of nematophagous fungi at 3 and 5 days after incubation	119
5.8	Effect of pH on growth of nematophagous fungi at 7 and 10 days after incubation	120
5.9	Effect of pH on sporulation of nematophagous fungi at 10 days after incubation	121
5.10	Effect of various insecticides on growth of nematophagous fungi on potato dextrose agar at 3 days after incubation	126

LIST OF TABLES (CONTINUED)

Table		Page
5.11	Effect of various insecticides on growth of nematophagous fungi on potato dextrose agar at 5 days after incubation	127
5.12	Effect of various insecticides on growth of nematophagous fungi on potato dextrose agar at 7 days after incubation	128
5.13	Effect of various insecticides on growth of nematophagous fungi on potato dextrose agar at 10 days after incubation	129
5.14	Effect of various insecticides on sporulation of nematophagous fungi on potato dextrose agar at 10 days after incubation	130
5.15	Effect of various fungicides on growth inhibition of nematophagous fungi on potato dextrose agar at 3 days after incubation	133
5.16	Effect of various fungicides on growth inhibition of nematophagous fungi on potato dextrose agar at 5 days after incubation	134
5.17	Effect of various fungicides on growth inhibition of nematophagous fungi on potato dextrose agar at 7 days after incubation	135

LIST OF TABLES (CONTINUED)

Table		Page
5.18	Effect of various fungicides on growth inhibition of nematophagous fungi on potato dextrose agar at 10 days after incubation	136
5.19	Effect of various fungicides on sporulation of nematophagous fungi on potato dextrose agar at 10 days after incubation	137
5.20	Effect of various herbicides on growth inhibition of nematophagous fungi on potato dextrose agar at 3 days after incubation	139
5.21	Effect of various herbicides on growth inhibition of nematophagous fungi on potato dextrose agar at 5 days after incubation	140
5.22	Effect of various herbicides on growth inhibition of nematophagous fungi on potato dextrose agar at 7 days after incubation	141
5.23	Effect of various herbicides on growth inhibition of nematophagous fungi on potato dextrose agar at 10 days after incubation	142

LIST OF TABLES (CONTINUED)

Table		Page
5.24	Effect of various herbicides on the sporulation of nematophagous fungi on potato dextrose agar at 10 days after incubation	143
6.1	Effect of seven solid substrate media on sporulation of nematophagous fungi at 21 days after incubation	160
6.2	Effect of eight liquid media on fresh weight biomass of three nematophagous fungi at 14 days after incubation	165
6.3	Effect of eight liquid media on dry weight biomass of three nematophagous fungi at 14 days after incubation	165
6.4	Effect of eight liquid media on sporulation of three nematophagous fungi at 14 days after incubation	166
6.5	Effect of eight liquid media on sporulation of three nematophagous fungi at 7 days after pouring to sterilized Petri dishes and incubation at $27\pm 1^{\circ}\text{C}$	166
7.1	The effect of nematophagous fungi amended media to seedling emergent at 7 and 14 days after planting	188
7.2	Effect of fungal biomass amended with medium on head lettuce seedling grow that 30 days after planting	190

LIST OF TABLES (CONTINUED)

Table		Page
7.3	Effect of nematophagous fungi-amended seedling application on head lettuce seedling growth at 60 days after transplantation in pots containing root-knot nematodes	194
7.4	Effect of biological agent (nematophagous fungi) application compared fermented and without fermented method 7 days before transplantation on head lettuce growth at 60 days	196
7.5	Effect of biological agent (nematophagous fungi) application comparing fermented and without fermented method 7 days before transplantation on baby cos lettuce growth at 60 days	198
7.6	Effect of fungal-amended seedling compared two media on head lettuce grow that 60 days after transplantation in root-knot nematode infested area	202
7.7	Effect of various fungal biomass formulations on head lettuce growth at 60 days after transplantation in root-knot nematode infested area (Area 1)	206
7.8	Effect of various fungal biomass formulations on head lettuce growth at 60 days after transplantation in root-knot nematode infested area (Area 2)	209

LIST OF FIGURES

Figure		Page
2.1	Morphological features of male and female plant parasitic nematodes	10
2.2	Morphological features of plant parasitic nematodes	11
2.3	Life cycle of an ectoparasitic nematode	15
2.4	The life cycle of <i>Rotylenchulus</i> (Reniform nematode)	16
2.5	Life cycle of a typical migratory endoparasitic nematode	17
2.6	Cross section of a soybean root depicting the life cycle of the soybean cyst nematode, <i>Heterodera glycines</i>	18
2.7	Root-knot nematode infections of (A) pawpaw, (B) parsley and (C) noni	21
2.8	Disease cycle and epidemiology of root knot nematode	24
2.9	Development stages of <i>Meloidogyne</i> spp.	25
2.10	Root-knot nematode damage to carrot roots and potato	27
2.11	Biology of nematophagous fungi	31

LIST OF FIGURES (CONTINUED)

Figure		Page
2.12	A phylogenetic tree based on the sequences of 18S rDNA showing the relationships among the nematode-trapping fungi and the position of this clade among species from the Pezizales (P), Leotiales (L) and Calciales (C)	36
2.13	Trapping mechanism of constricting rings of <i>Arthrobotrys brochopaga</i>	41
3.1	Sampling pattern for damaged area or infected patch in a crop	44
3.2	Location of soil samplings in river basin	50
3.3	Characteristics of captured nematodes (ne) or egg (eg) by special structures (ss) of some nematophagous fungi	55
4.1	Schematic representation of rDNA with primer ITS1 and ITS4 localization (arrows)	68
4.2	Characteristics of eight fungal colony textures on corn meal agar 10 days after incubation	74
4.3	Conidiophore patterns (A) and conidia (B) of <i>Arthrobotrys oligospora</i> isolate DLO1-001 on micro-culture technique	75
4.4	Conidiophore patterns (A) and conidia (B) of <i>Arthrobotrys oligospora</i> isolate MTI2-001 on micro-culture technique	76

LIST OF FIGURES (CONTINUED)

Figure		Page
4.5	Conidiophore patterns (A) and conidia (B) of <i>Arthrobotrys conoides</i> isolate API3-001 on micro-culture technique	77
4.6	Conidiophore patterns (A) and conidia (B) of <i>Monacrosporium thaumasium</i> isolate JDI1-001 on micro-culture technique	78
4.7	Conidiophore patterns (A) and conidia (B) of <i>Monacrosporium thaumasium</i> isolate MPI1-003 on micro-culture technique	79
4.8	Conidiophore patterns (A) and conidia (B) of <i>Arthrobotrys musiformis</i> isolate MSO1-001 on micro-culture technique	80
4.9	Conidiophore patterns (A) and conidia (B) of <i>Paecilomyces lilacinus</i> isolate WJI1-003 on micro-culture technique	81
4.10	Conidiophore patterns (A) and conidia (B) of <i>Pochonia chlamydosporia</i> isolate KJO1-003 on micro-culture technique	82
4.11	Amplification of the partial ITS region for species identification of eight nematophagous fungi by PCR using the internal transcribed spacer primers: ITS1 and ITS4	84
4.12	One of 6 equally most parsimonious trees inferred from a heuristic search of the ITS1-5.8S-ITS2 rDNA sequences alignment of 44 isolates of <i>Arthrobotrys</i> and related genera	88

LIST OF FIGURES (CONTINUED)

Figure		Page
5.1	Colony characterizations of four nematophagous fungi on media 10 days after incubation (A-D)	106
5.2	Colony characterizations of four nematophagous fungi on media 10 days after incubation (E-H)	107
5.3	Colony characterizations of four nematophagous fungi comparing various temperatures on PDA 10 days after incubation (A-D)	111
5.4	Colony characterizations of four nematophagous fungi comparing various temperatures on PDA 10 days after incubation (E-H)	112
5.5	Colony characterizations of four nematophagous fungi comparing various light regimes on PDA 10 days after incubation (A-D)	116
5.6	Colony characterizations of four nematophagous fungi comparing various light regimes on PDA 10 days after incubation (E-H)	117
5.7	Colony characterizations of four nematophagous fungi comparing pH 3-10 on PDA 10 days after incubation (A-D)	122

LIST OF FIGURES (CONTINUED)

Figure		Page
5.8	Colony characterizations of four nematophagous fungi comparing pH 3-10 on PDA 10 days after incubation (E-H)	123
5.9	Sampling of colony characterizations of three nematophagous fungi comparing effect from herbicides on PDA after 10 days incubation	144
6.1	Seven solid substrates in polypropylene bags at 21 days after incubation	161
6.2	Fungal characterizations on seven solid substrates at 21 days after incubation	161
6.3	Characterizations of <i>Arthrobotrys oligospora</i> isolate MTI2-001 in eight liquid media at 14 days after incubation	167
6.4	Characterizations of <i>Arthrobotrys conoides</i> isolate API3-001 in eight liquid media at 14 days after incubation	168
6.5	Characterizations of <i>Paecilomyces</i> sp. isolate WJI1-003 in eight liquid media at 14 days after incubation	169
7.1	Characterizations of head lettuce seedling on different fungal biomasses amended with Medium 1	191

LIST OF FIGURES (CONTINUED)

Figure		Page
7.2	Characterizations of head lettuce seedling on different fungal biomasses amended with Medium 2	191
7.3	Characterizations of head lettuce seedling growth at 60 days after application of the fungal biological agents comparing fermented and without fermented method 7 days before transplantation	199
7.4	Characterizations of baby cos lettuce seedling growth at 60 days after application of the fungal biological agents comparing fermented and without fermented method 7 days before transplantation	199
7.5	Head lettuce seedling grown in field application 7 days after transplantation in a root-knot nematode infested area during raining	203
7.6	Characterizations of head lettuce after trimming of diseased leaves comparing fungal biomass applications at 60 days after transplantation in a root-knot nematode infested area	203
7.7	Characterizations of the tested plot of head lettuce and famer on Area 1 (left) and Area 2 (right)	210

LIST OF FIGURES (CONTINUED)

Figure		Page
7.8	Characterizations of head lettuce at 60 days after transplantation in root-knot nematodes infected area comparing various fungal biomass formulations	210

LIST OF PROCEEDING AND PUBLICATIONS

1. **Mensin, S.**, Lumyong, P. & Akarapisan, A. 2008. Screening and Production of Antagonistic Fungi (*Arthrobotrys* sp.) for Controlling Root Knot Nematode in Head Lettuce. p. 50. In The 3th Annual Meeting of Thai Mycological Association and Mycological Conference in Thailand. October 11, 2008. Khon Kaen University, Khon Kaen, Thailand. (Poster presentation in English).
2. **Mensin, S.** & To-anun, C. 2012. Screening and Pre-test of Antagonistic Fungi Efficiency for Controlling Root-knot Nematode on Highland Vegetable Productions. p. 24. In: The 10th National Plant Protection Conference. February 22-24, 2012. Chiang Mai Khum Phucome Residence Hotel, Chiang Mai, Thailand. (Oral presentation in Thai).
3. **Mensin, S.**, Cheewangkoon, R., Valyasevi, S. & To-anun, C. 2012. Influence of Fungicide and Herbicide to Nematophagous Fungi Against Root-knot Nematode. p. 15. In: The 6th Thai Mycological Conference & The Annual Meeting of Thai Mycological Association (TMA). March 6, 2012. Rama Gardens Hotel, Bangkok, Thailand. (Oral presentation in English).
4. **Mensin, S.**, Soytong, K., McGovern, R. J. & To-anun, C. 2012. Selection of Efficient Nematophagous Fungi Against Root-knot Nematodes in the Highland Cultivated Area. *Journal of Agricultural Technology*. **8**(7): 2259-2272.

5. **Mensin. S.**, Soyong, K., McGovern, R. J. & To-anun, C. 2013. Effect of Agricultural Pesticides on the Growth and Sporulation of Nematophagous Fungi. *Journal of Agricultural Technology*. **9**(4): 953-961.