CONTENTS

Acknowledgement	c
Abstract in English	e
Abstract in Thai	h
List of Tables	n
List of Figures	r
Chapter 1 Introduction	
1.1 Rationale	1
1.2 Fusarium wilt disease in tomato	3
1.3 Biological control	16
1.4 Induced resistance	18
1.5 Actinomycetes	27
1.6 The objectives of this study	36
1.7 Education/application advantages	37
1.8 Scope of this study	37
Chapter 2 Isolation, morphological characterization and pathogenicity	
test of Fusarium oxysporum f. sp. lycopersici (Fol) causing Fusarium	
wilt in tomato	
2.1 Introduction	38
2.2 Materials and methods	39
2.3 Results	44
2.4 Discussion	62
2.5 Conclusions	64

CONTENTS (CONTINUED)

Chapter 3	In vitro	selection	of Strepton	<i>yces</i> strain	against	Fusarium	wilt
pathogen u	using dua	al culture	method				

3.1	Introduction	66
3.2	Materials and methods	68
3.3	Results	71
3.4	Discussion	73
3.5	Conclusions	75
Chapter 4	Induction of pathogenesis-related (PR) genes expression in	
tomato ag	ainst Fusarium wilt disease by Streptomyces	
4.1	Introduction	76
4.2	Materials and methods	78
4.3	Results	83
4.4	Discussion	91
4.5	Conclusions	94
Chapter 5	Evaluation of Streptomyces to control Fusarium wilt disease	
in tomato	under greenhouse conditions	
5.1	Introduction SUM1200816816800101	96
5.2	Materials and methods	98
5.3	Results	103
5.4	Discussion	121
5.5	Conclusions	125

CONTENTS (CONTINUED)

Chapter 6 Discussion	
6.1 General discussion 12	6
6.2 Conclusions 13	4
6.3 Future perspectives and recommendations 13	5
References 13	6
Appendix A 16	9
Appendix B 17	2
List of publications 18	9
List of presentations and proceeding	0
Curriculum Vitae 19	2
ລິບສິກລິ້ມหາວົກຍາລັຍເຮີຍວໃหມ່ Copyright [©] by Chiang Mai University All rights reserved	

LISTS OF TABLES

Table 1.1	Resistance and susceptibility of 4 differential tomato	
	varieties to different races of Fusarium oxysporum f. sp.	
	lycopersici (Fol)	14
Table 1.2	Classification of pathogenesis related proteins	23
Table 1.3	Elicitors of plants	26
Table 2.1	Resistance and susceptibility of 5 differential tomato	
	varieties used in this study to different races of Fol	44
Table 2.2	Number of Fol isolates causing Fusarium wilt in tomato	
	from commercial fields at Doi Inthanon National Park,	
	Chiang Mai, Thailand	46
Table 2.3	List of Fol isolates causing Fusarium wilt in tomato cv.	
	'Cherry' and 'Thomas' from commercial fields at Doi	
	Inthanon National Park, Chiang Mai, Thailand	48
Table 2.4	Disease severity index (DSI) and pathogenicity group of Fol	
	isolates causing Fusarium wilt in tomato seedlings cv.	
	'Bonny Best' (susceptible to Fusarium wilt)	56
Table 2.5	Correlation between colony color of Fusarium oxysporum	
	f. sp. lycopersici isolates causing Fusarium wilt and disease	
	severity index (DSI) in tomato seedlings cv. 'Bonny Best'	
	(susceptible to Fusarium wilt)	59
Table 2.6	Randomly selected isolates from the pathogenic group of	
	Fol in tomato seedlings cv. 'Bonny Best' (susceptible to	
	Fusarium wilt)	60
Table 2.7	Disease severity index (DSI) of selected Fol to isolates in	
	tomato seedlings cv. 'Bonny Best' (susceptible to Fusarium	
	wilt) and cv. 'EWS-37434 (resistant to Fusarium wilt)	61

LISTS OF TABLES (CONTINUED)

		Page
Table 2.8	Race identification of Fusarium oxysporum f. sp. lycopersici	
	(Fol) isolate FolCK_117 using 5 tomato varieties with	
	different races	62
	9081818B	
Table 3.1	Efficacy of <i>Streptomyces</i> species on the inhibition of the	
	colony growth and conidia production of Fol isolate	
	FolCK_117 causing Fusarium wilt in tomato on GYM agar	
	at 7 days	72
Table 4.1	Experimental treatment design for induction of defense	
	mechanisms	80
Table 4.2	Primers designed from gene sequences (GenBank) and used	
	in qRT-PCR to amplify the genes encoding the selected <i>PR</i>	
	proteins in tomato	83
Table 4.3	qRT-PCR analysis of PR-1a gene expression in tomato	
	leaves in response to the application of Streptomyces NSP3	
	with or without challenge inoculation with FolCK_117 at 0,	
	3, 6, 12 and 24 h post- <i>Fol</i> inoculation	86
Table 4.4	qRT-PCR analysis of <i>Chi3</i> gene expression in tomato leaves	
	in response to the application of <i>Streptomyces</i> NSP3 with or	
1	without challenge inoculation with <i>Fol</i> CK_117 at 0, 3, 6, 12	
	and 24 h post- <i>Fol</i> inoculation	87
Table 4.5	qRT-PCR analysis of <i>Chi9</i> gene expression in tomato leaves	
	in response to the application of <i>Streptomyces</i> NSP3 with or	
	without challenge inoculation with <i>Fol</i> CK_117 at 0, 3, 6, 12	
	and 24 h post- <i>Fol</i> inoculation	88
	•	

LISTS OF TABLES (CONTINUED)

		Page
Table 4.6	qRT-PCR analysis of CEVI-1 gene expression in tomato	
	leaves in response to the application of Streptomyces NSP3	
	with or without challenge inoculation with <i>Fol</i> CK_117 at 0,	
	3, 6, 12 and 24 h post- <i>Fol</i> inoculation.	89
Table 5.1	Seed germination testing of tomato seeds cv. 'Bonny Best'	
	and 'EWS-37434' after the application of Streptomyces	
	NSP3 as seed treatment for 12 h using standard roll towel	105
	method	
Table 5.2	Evaluation of seed vigour index of tomato seeds cv. 'Bonny	
	Best' and 'EWS-37434' after application of Streptomyces	
	NSP3 as seed treatment for 12 h using standard roll towel	
	method	106
Table 5.3	Evaluation of Fusarium wilt disease severity, caused by	
	FolCK_117, of tomato plants cv. 'Bonny Best' and EWS-	
	37434 after the application of Streptomyces NSP3 as the	
	combination of seed treatment and soil application	109
Table 5.4	Colonization dynamics of Streptomyces NSP3 inner root	
	tissues of tomato plants cv. 'Bonny Best' and EWS-37434	
	by Streptomyces NSP3 application of Streptomyces NSP3	
	every 14 days after transplanting	112
Table 5.5	Colonization dynamics of Streptomyces NSP3 in potting soil	
	tissues of tomato plants cv. 'Bonny Best' and EWS-37434	
	by Streptomyces NSP3 application of Streptomyces NSP3	
	every 14 days after transplanting	113

LISTS OF TABLES (CONTINUED)

Page

116

117

Table 5.6Effect of Streptomyces NSP3 on growth parameters of
tomato plants cv. 'Bonny Best' (susceptible to Fusarium
wilt disease) after the application of seed treatment and soil
application in vivo

- Table 5.7Effect of Streptomyces NSP3 on growth parameters of
tomato plants cv. 'EWS-37434' (resistant to Fusarium wilt
disease) after the application of seed treatment and soil
application in vivo
- Table 5.8 Effect of *Streptomyces* NSP3 on increasing in percentage of tomato plants growth parameters cv. 'Bonny Best' and EWS-37434 after the application of seed treatment and soil application *in vivo*

GMAI

118

ลิ<mark>ขสิทธิ์มหาวิทยาลัยเชียงใหม่</mark> Copyright[©] by Chiang Mai University All rights reserved

LISTS OF FIGURES

Figure 1.1	Disease cycle of Fusarium wilt disease in tomato	9
Figure 1.2	Schematic representation of three spore types of Fusarium	
	oxysporum	12
Figure 1.3	A pictorial comparison of the two best characterized forms	
	of induced resistance in plants, including systemic acquired	
	resistance (SAR) and induced systemic resistance (ISR)	21
Figure 1.4	Elicitor signal transduction mechanism activating plant	
	primary immune response of plant in plant-pathogen	
	interaction	27
Figure 1.5	Life cycle of Streptomyces species	33
Figure 2.1	Diagram for coding the <i>Fol</i> isolates	40
Figure 2.2	Fusarium wilt symptoms on naturally-infected tomato plants	
	from commercial fields at Doi Inthanon National Park,	
	Chiang Mai, Thailand	45
Figure 2.3	Morphological characterization of Fol isolates grown on	
	PDA for 10 days causing Fusarium wilt in tomato	47
Figure 2.4	Disease severity index (DSI) of Fusarium wilt in tomato at	
	21 days after inoculation with Fol	55
Figure 2.5	Vascular browning discoloration of tomato seedlings cv.	
	'Bonny Best' at 21 days after inoculation with Fol	55
Figure 2.6	Adventitious root development of tomato seedlings cv.	
	'Bonny Best' at 21 days after inoculation with Fol	55

LISTS OF FIGURES (CONTINUED)

		Page
Figure 3.1	Dual culture test layout of Streptomyces against colony	
	growth of Fol causing Fusarium wilt in tomato on GYM	70
Figure 3.2	Efficacy of Streptomyces species on the colony growth and	
	conidia production of Fol isolate FolCK_117 causing	
	Fusarium wilt	71
Figure 3.3	Dual culture test between antagonistic Streptomyces strain	
	NSP3 and Fol isolate FolCK_117 causing Fusarium wilt in	
	tomato on GYM at 7 days	73
Figure 4.1	Real-time qPCR analysis of PR gene expression in tomato	
	leaves in response to application of Streptomyces NSP3 with	
	or without challenge inoculation with <i>Fol</i> CK_117.	90
	I Z LIGHTA	
Figure 5.1	Seed germination categories	104
Figure 5.2	Comparison between normal germination tomato seedlings	
	with or without seed treatment of Streptomyces NSP3	106
Figure 5.3	Evaluation of Fusarium wilt disease severity, caused by	
	FolCK_117, of tomato plants cv. 'Bonny Best' and EWS-	
	37434 after application of Streptomyces NSP3 as	
	combination of seed treatment and soil application.	108
Figure 5.4	Appearance of vascular browning discoloration due to	
	Fusarium wilt symptoms, caused by FolCK_117, of tomato	110
Figure 5.5	plants cv. 'Bonny Best' and EWS-37434 after application of	
	Streptomyces NSP3 on harvesting day.	
	Adventitious root development of tomato plants inoculated	
	with FolCK_117 on harvesting day.	110

LISTS OF FIGURES (CONTINUED)

Figure 5.6	The colonization dynamics of biocontrol strain Streptomyces	
	in potting soil and root tissues of tomato cv. 'Bonny Best'	
	and cv. 'EWS-37434' done by challenge inoculation with	
	or without FolCK_117 every 14 day after transplanting	114
Figure 5.7	Fresh roots of tomato plants cv. 'Bonny Best' and EWS-	
	37434 after application of Streptomyces NSP3 on harvesting	
	day S	119
Figure 5.8	Fruits of tomato plants cv. 'Bonny Best' and EWS-37434	
	after application of Streptomyces NSP3 on harvesting day	120
	Ial Yella	
	EL MARIS	
	A A A	
	ALL BSI'	
	TAI UNIVER	

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่ Copyright[©] by Chiang Mai University All rights reserved