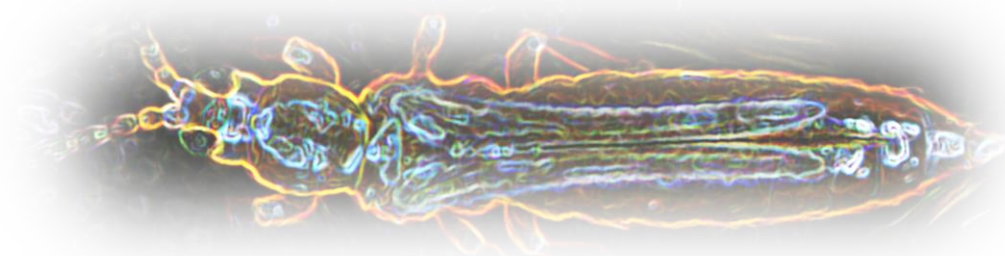


Successful R&D and Marketing Strategy for *Beauveria bassiana* ERL836 GR and WP for thrips management



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³ Crop Protection Research Institute of **LG Chemical-FarmHannong Inc.**, Korea



















Oct 24, 2023



Global registration of microbial insecticide

Global bioinsecticide: expanding of fungal insecticide market

(Biopesticides of 2014~2022, Agrow 2020 & Local News)

2014	2015	2016	2017	2018	2019
Company & active Ingredient	Company & active Ingredient	Company & active Ingredient	Company & active Ingredient	Company & active Ingredient	Company & active Ingredient
AgBiTech <i>Helicoverpa zea</i> NPV (Heligen/US)	Anatis Bioprotection <i>Beauveria bassiana</i> ANT-03 (Bioceres/US) 	Andermatt Biocontrol <i>Cydia pomonella</i> GV (Madex/Spain) <i>Helicoverpa armigera</i> NPV (Verpavex/Brazil)	Bayer <i>Paecilomyces liacinus</i> 251 (BioAct Prime/Greece) 	AgBiTech <i>Chrysodeixis includens</i> NPV (Surtiva/Argentina)	BASF <i>B. bassiana</i> PPRI 5339 (Approved/EU) 
Andermatt Biocontrol <i>Helicoverpa armigera</i> NPV (Helicovex/Australia)	Andermatt Biocontrol <i>Autographa californica</i> NPV (Loopex/Canada) <i>Cydia pomonella</i> GV (France)	AEF Global <i>Bt kurstaki</i> EVB-113-19 (US)	Arysta LifeScience <i>Beauveria bassiana</i> 147 (EU) <i>Beauveria bassiana</i> NPP111B005 (EU) 	Andermatt BioControl <i>Hlicoverpa armigera</i> NPV BV-0003 (Helicovex/Canada)	Exosect <i>B. bassiana</i> IMI389521 (Approved/EU) 
Marrone Bio Innovations <i>Burkholderia</i> spp A396 (Venerate/US) 	Andermatt Biocontrol/FMC <i>Helicoverpa armigera</i> NPV (Helicovex/Brazil)	AbBiTech <i>Spodoptera frugiferda</i> NPV (Fawligen/US)	BASF BroadBand® <i>Beauveria bassiana</i> PPRI5339 (Broadband/Australia) (Velifer/Canada) 	BASF <i>B. bassiana</i> PPRI 5339 (Velifer/Canada) 	Nufarm cis-jasmone (<i>B. amyloliquefaciens</i>) (Trunemco/US) 
Phyllom BioProducts <i>Bt galleriae</i> (GrubGone/US)	Bayer Terpenoid blend QRD460 (EU)	Bayer <i>Bacillus firmus</i> I-1582 (Poncho Votivo/New Zealand /Clothianidin) 	FarmHannong <i>Beauveria bassiana</i> ERL836 (Chongchaesak GR/Korea) 	Phyllom Bios <i>Bt galleriae</i> SDS-502 (GrubGONE/Canada)	FarmHannong <i>Beauveria bassiana</i> ERL836 (Chongchaesak WP/Korea) 
	Syngenta <i>Pasteuria nishizawae</i> Pn1 (Clariva/Canada)	Marrone Bio Innioations <i>Chromobacterium subtsugae</i> PRAA4-1T (Grandevo/Mexico) <i>Burkholderia rinojensis</i> A396 (Majestene/Mexico) 	Syngenta <i>Pasteuria nishizawae</i> Pn1 (Approved/EU) 	Phyllom Bios <i>Bt galleriae</i> SDS-502 (GrubGONE/Canada)	FarmHannong <i>Beauveria bassiana</i> ERL836 (Chongchaesak WP/Korea) 
	Valent Bioscience <i>Bt aizawai</i> ABTS-1587 (Xentari/Canada)	Rizoflora Biotecnologia <i>Pochonia chlamydosporia</i> PC10 (Rizotec/Brazil) 	BoteGHA ES EMULSIFIABLE SUSPENSION MYCOINSECTICIDE 	Phyllom Bios <i>Bt galleriae</i> SDS-502 (GrubGONE/Canada)	FarmHannong <i>Beauveria bassiana</i> ERL836 (Chongchaesak WP/Korea) 
				2021 Company & active Ingredient	2022 Company & active Ingredient
				Certis Biologiclas <i>Beauveria bassiana</i> GHA 2% ES (Chongchaestop GR, WP /Korea)	Kyungnong/Global Agro <i>Beauveria bassiana</i> JEF-507 (Chongchaestop GR, WP /Korea)

Entomopathogenic fungi

Insect-killing fungi: broad spectrum (but technically short storage and environment-dependent)

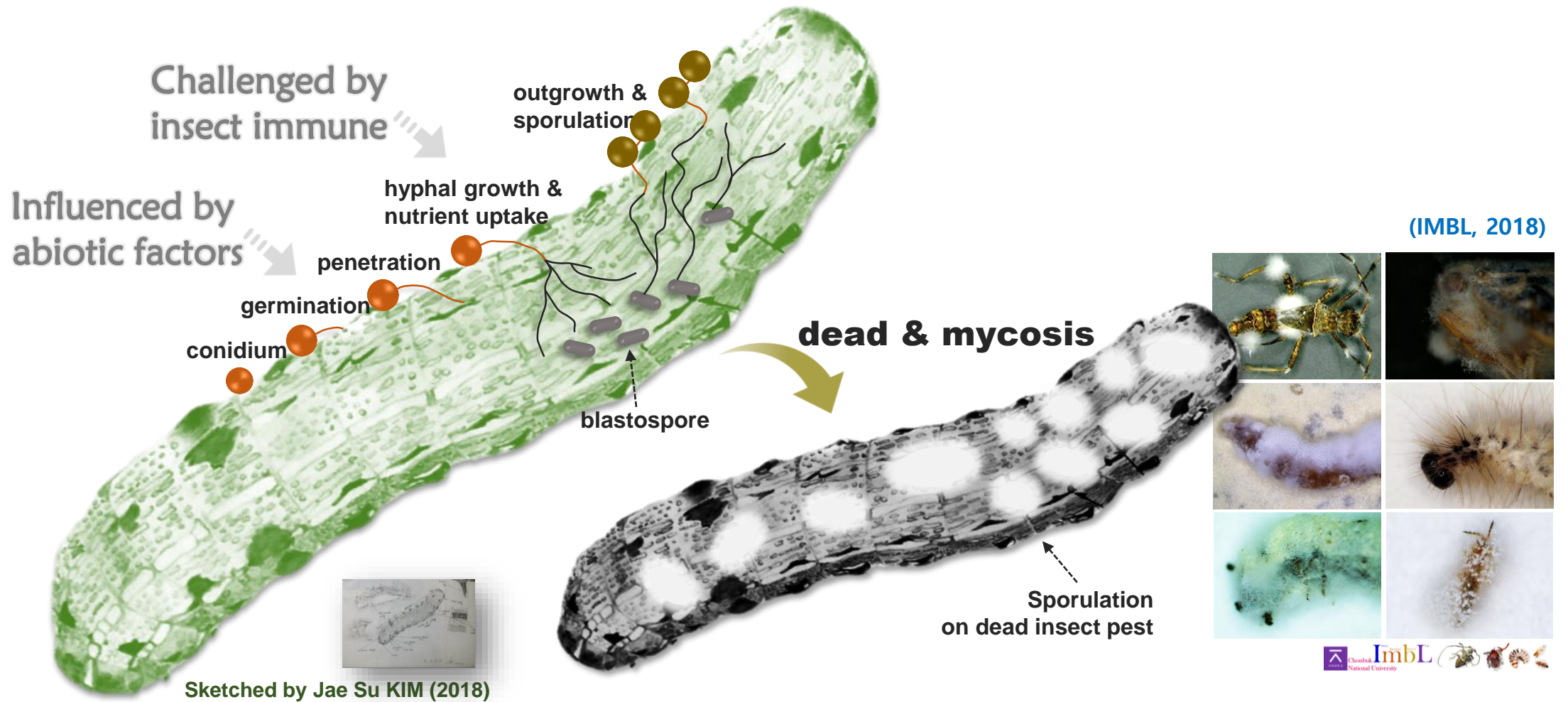


IMBL 곤충병원성 진균 데이터베이스
Insect Microbiology & Biotechnology Laboratory



Mode of action

Fungal mode of action: hyphal penetration, release of toxic substances and conidial transferring



A new approach: ecological biocontrol

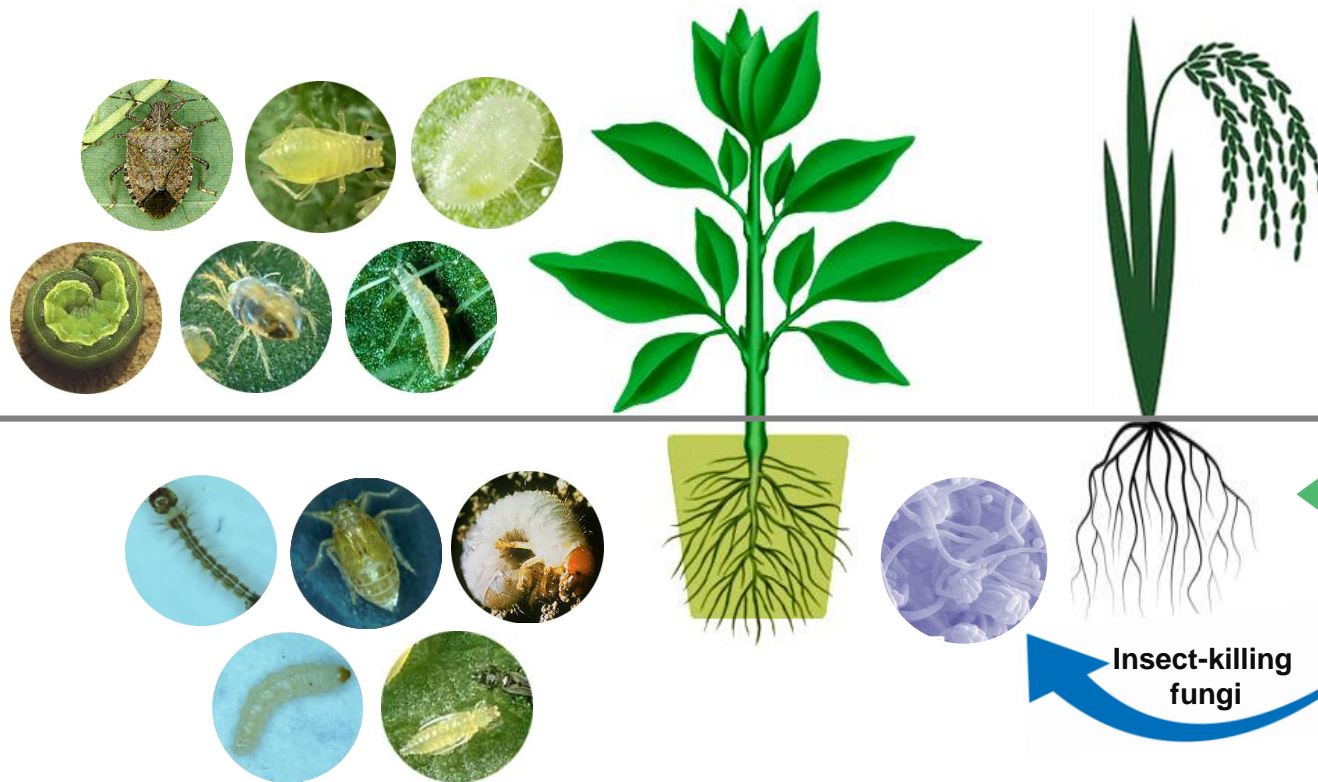
Application strategy: where fungi can colonize + reducing residual issue of chemicals



(Lee and Lee et al., Scientific Report, 2018)

Places for microbial application in markets

We need to understand the ecology of target insects.



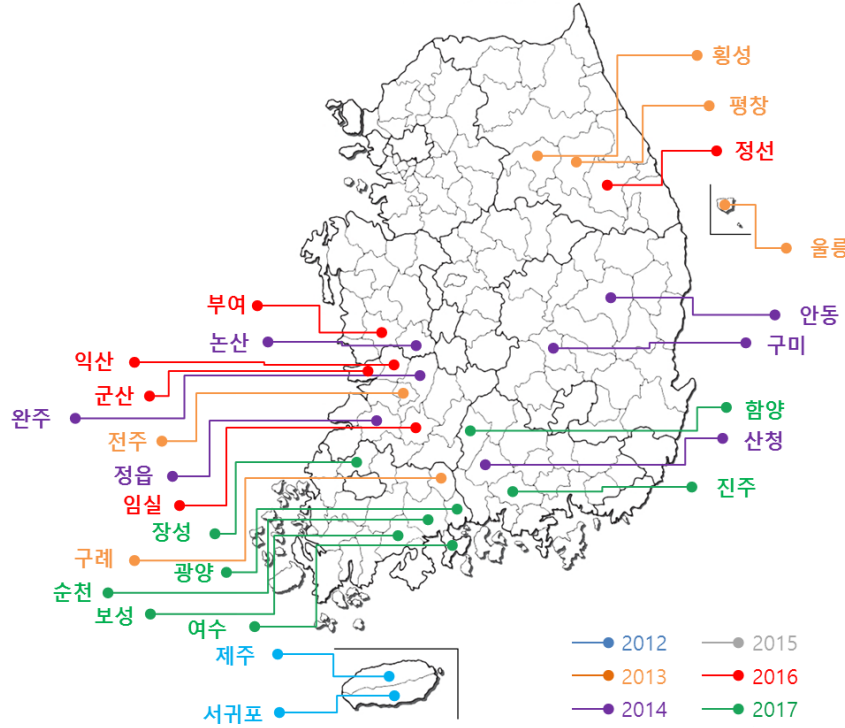
Soil or water as insect habitat

Insect-killing fungi can grow in soil or water very well!

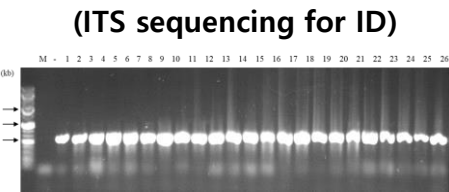
Jeonbuk Nat. Univ. Entomopathogenic Fungi (JEF)

Fungal library: Insect-baiting method (*Tenebrio molitor*) in Korea

(Kim et al., J Asia-Pacific Entomol. 2018)



(Geographical data for soil sampling)



(ITS sequencing for ID)



(Bioassay against *T. molitor* larvae)



No.	Original Code	Genus	Species	Location	Conidia Color						
1	PWS047	<i>Metarhizium</i>	<i>anisopliae</i>	Jeonju-si, Jeollabuk-do	Green						
2	PWS048	<i>Metarhizium</i>	<i>anisopliae</i>	Jeonju-si, Jeollabuk-do	Green						
3	PV	No.	Original Code	Genus	Species	Location	Conidia Color				
4	PV	26	MMR018	<i>Isaria</i>	<i>fumosorosea</i>	Iksan-si, Jeollabuk-do	Pink				
5	PV	27	MMR020	<i>Metarhizium</i>	<i>anisopliae</i>	Iksan-si, Jeollabuk-do	Green				
6	PV	28	MM	No.	Original Code	Genus	Species	Location	Conidia Color		
7	PV	29	MM	51	MOS019	<i>Beauveria</i>	<i>bassiana</i>	Gunsan-si, Jeollabuk-do	White-yellow		
8	PV	30	MM	52	MOS020	<i>Metarhizium</i>	<i>anisopliae</i>	Gunsan-si, Jeollabuk-do	Green		
9	UJ	31	MM	53	MC	No.	Original Code	Genus	Species	Location	Conidia Color
10	MM	32	RG	54	MC	76	RBS011	<i>Isaria</i>	<i>fumosorosea</i>	Gunsan-si, Jeollabuk-do	Pink
11	MM	33	RG	55	MC	76	RBS011	<i>Isaria</i>	<i>fumosorosea</i>	Gunsan-si, Jeollabuk-do	Pink
12	MM	34	RG	56	MC	77	RBS012	<i>Beauveria</i>	<i>bassiana</i>	Gunsan-si, Jeollabuk-do	Pink
13	MM	35	RG	57	MC	77	RBS012	<i>Beauveria</i>	<i>bassiana</i>	Gunsan-si, Jeollabuk-do	Pink
14	MM	36	MC	58	MC	78	RBS013	<i>Codyceps</i>	<i>brongiartii</i>	Gunsan-si, Jeollabuk-do	Pink
15	MM	37	MC	59	MC	79	RBS016	<i>Metarhizium</i>	<i>anisopliae</i>	Gunsan-si, Jeollabuk-do	Green
16	MM	38	MC	60	MC	80	RBS017	<i>Beauveria</i>	<i>bassiana</i>	Gunsan-si, Jeollabuk-do	White-yellow
17	MM	39	MC	61	MC	80	RBS017	<i>Beauveria</i>	<i>bassiana</i>	Gunsan-si, Jeollabuk-do	White-yellow
18	MM	40	MC	62	MC	81	RBS018	<i>Codyceps</i>	<i>brongiartii</i>	Gunsan-si, Jeollabuk-do	Pink
19	MM	41	MC	63	MC	82	RBS021	<i>Beauveria</i>	<i>bassiana</i>	Gunsan-si, Jeollabuk-do	White-yellow
20	MM	42	MC	64	MC	83	RBS024	<i>Beauveria</i>	<i>bassiana</i>	Gunsan-si, Jeollabuk-do	White-yellow
21	MM	43	MC	65	MC	83	RBS024	<i>Beauveria</i>	<i>bassiana</i>	Gunsan-si, Jeollabuk-do	White-yellow
22	MM	44	MC	66	MC	84	RBS025	<i>Beauveria</i>	<i>bassiana</i>	Gunsan-si, Jeollabuk-do	White-yellow
23	MM	45	MC	67	MC	85	RBS026	<i>Beauveria</i>	<i>bassiana</i>	Gunsan-si, Jeollabuk-do	White-yellow
24	MM	46	MC	68	MC	86	MMD001	<i>Metarhizium</i>	<i>flavoviride</i>	Jeongseon-gun, Gangwon-do	Green
25	MM	47	MC	69	RE	87	MMD002	<i>Metarhizium</i>	<i>robertsii</i>	Jeongseon-gun, Gangwon-do	Green
26	MM	48	MC	70	RE	87	MMD002	<i>Metarhizium</i>	<i>robertsii</i>	Jeongseon-gun, Gangwon-do	Green
27	MM	49	MC	71	RE	88	MMD004	<i>Metarhizium</i>	<i>robertsii</i>	Jeongseon-gun, Gangwon-do	Green
28	MM	50	MC	72	RE	88	MMD004	<i>Metarhizium</i>	<i>robertsii</i>	Jeongseon-gun, Gangwon-do	Green
29	MM	51	MC	73	RE	89	MMD005	<i>Isaria</i>	<i>fumosorosea</i>	Jeongseon-gun, Gangwon-do	Green
30	MM	52	MC	74	RE	90	MMD008	<i>Clonostachys</i>	<i>rosea</i>	Jeongseon-gun, Gangwon-do	Green
31	MM	53	MC	75	RE	91	MMD009	<i>Metarhizium</i>	<i>anisopliae</i>	Jeongseon-gun, Gangwon-do	Green
32	MM	54	MC	76	RE	92	MMD011	<i>Metarhizium</i>	<i>flavoviride</i>	Jeongseon-gun, Gangwon-do	Green

(Entomopathogenic fungal library construction)



Fungal library of JEF at IMBL



A big fungal library construction with international cooperation (>2,000 isolates)



- Beauveria bassiana* 41
- Beauveria* sp. 3
- Cylindrocarpon* sp. 1
- Fusarium* sp. 5
- Paecilomyces farinosus* 13
- Paecilomyces fumosoroseus* 1
- Verticillium lecanii* 24
- Verticillium* cf. *lamellirula* 1
- Verticillium* cf. *lecanii* 1

90

847



- Alternaria* sp. 1
- Beauveria bassiana* 342
- Beauveria* sp. 16
- Cephalosporium* sp. 6
- Cladosporium* sp. 2
- Entomophthora coronata* 21
- Epicoccum* sp. 1
- Fusarium* sp. 5
- Geotrichum* sp. 4
- Mariannaea* sp. 10
- Mariannaea* sp. 3
- Metarhizium anisopliae* 75
- Paecilomyces farinosus* 45
- Paecilomyces fumosoroseus* 27
- Paecilomyces lilacinum* 14
- Peziza ostracoderma* 2
- Rhinoctadiella* sp. 1
- Scopulariopsis* sp. 2
- Synnematium* sp. 1
- Trichoderma* sp. 32
- Verticillium lecanii* 60
- Verticillium* sp. 7
- unidentified 170

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13

- Beauveria bassiana* 1
- Paecilomyces farinosus* 8
- unidentified 4

322

- Aphanocladium album* 1
- Aspergillus* sp. 1
- Beauveria bassiana* 79
- Fusarium* sp. 10
- Metarhizium anisopliae* 96
- Paecilomyces farinosus* 49
- Paecilomyces fumosoroseus* 1
- Paecilomyces lilacinum* 9
- Paecilomyces* sp. 6
- Scopulariopsis* sp. 2
- Trichoderma* sp. 6
- Verticillium lecanii* 6
- Verticillium psalliottae* 4
- unidentified 52

國立中興大學
Taiwan
National Chung Hsing University
Department of Entomology

Jeonbuk ImbL National University
Republic of Korea

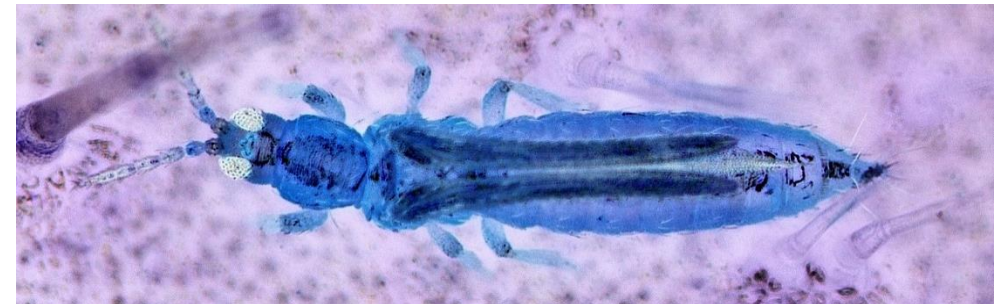
1000

- Beauveria bassiana* 219
- Beauveria* sp. 6
- Clonostachys* sp. 3
- Cordyceps* sp. 9
- Gibberella intermedia* 1
- Isaria* sp. 36
- Lecanicillium* sp. 6
- Metacordyceps* sp. 5
- Metarhizium anisopliae* 122
- Metarhizium* sp. 28
- Nomuraea rileyi* 3
- Paecilomyces* sp. 39
- Penicillium* sp. 4
- Pochonia* sp. 59
- Purpureocillium* sp. 18

Western flower thrips (*F. occidentalis*)



Resistance of thrips: alternative with different mode of action and environmentally sound



Pathogenesis of *B. bassiana* ERL836 against thrips

Insecticidal activity of ERL836: high activity against western flower thrips



Bioassay against thrips



Non-treated Control



Infected by ERL836

NIH National Library of Medicine National Center for Biotechnology Information *B. bassiana* ERL836 (GenBank GCA_010099065)

(Kim et al., SIP Gold Medal Award Video. 2018)

Growth

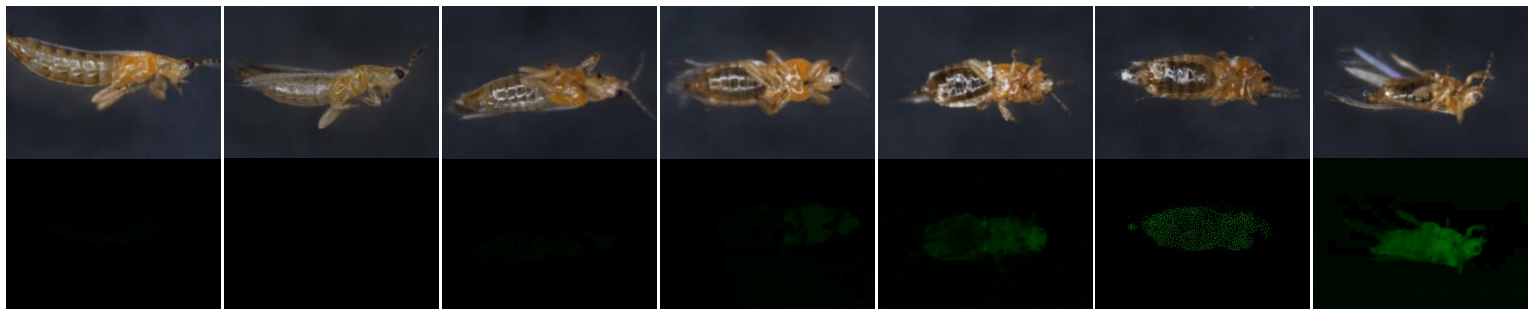
ERL836



Infection



ERL836-egfp



Before infection

Day 1

Day 2

Day 3

Day 4

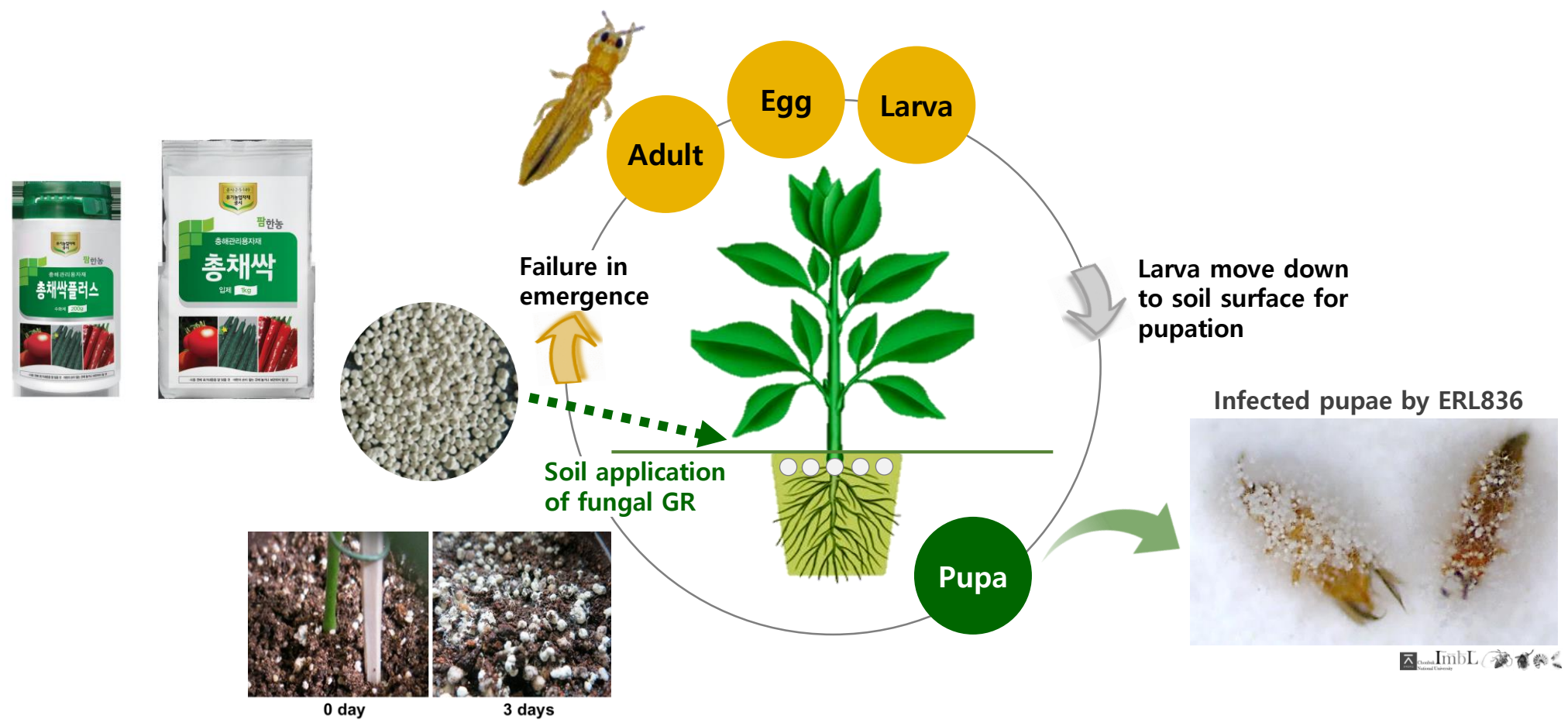
Day 5

Day 6

Concept of *B. bassiana* ERL836 for thrips management

New concept of application: targeting soil-dwelling stage of thrips

(Lee et al., 2017. BioControl; Skinner et al., 2012. Biological Control)



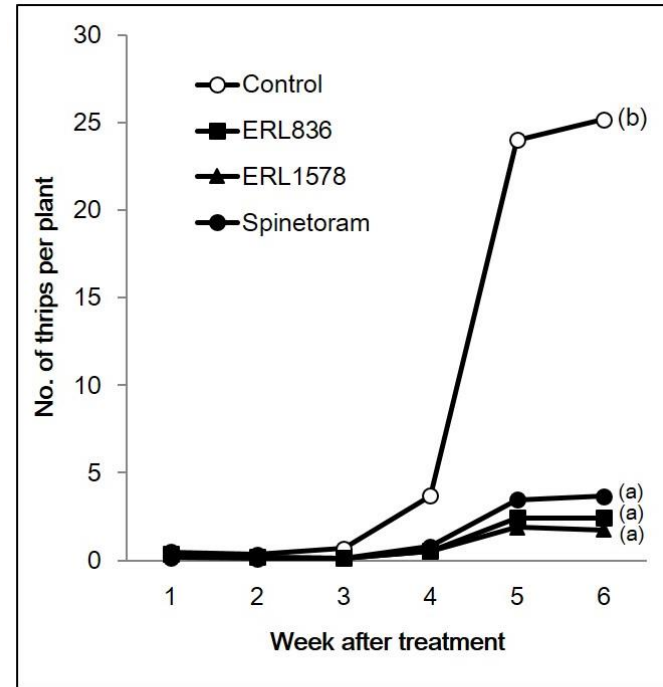
Field data of *B. bassiana* ERL836 GR against thrips

Field test : High performance in cucumber and rose (applied to many other crops)



0 day

7 days



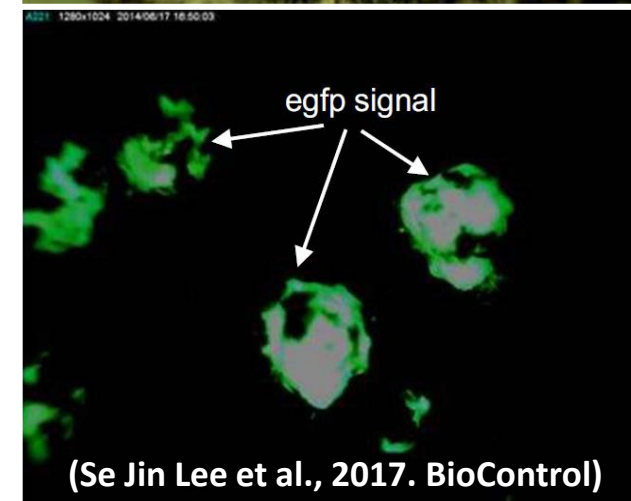
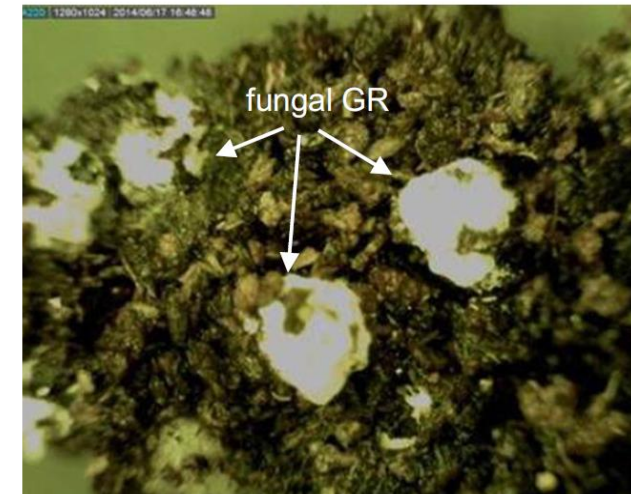
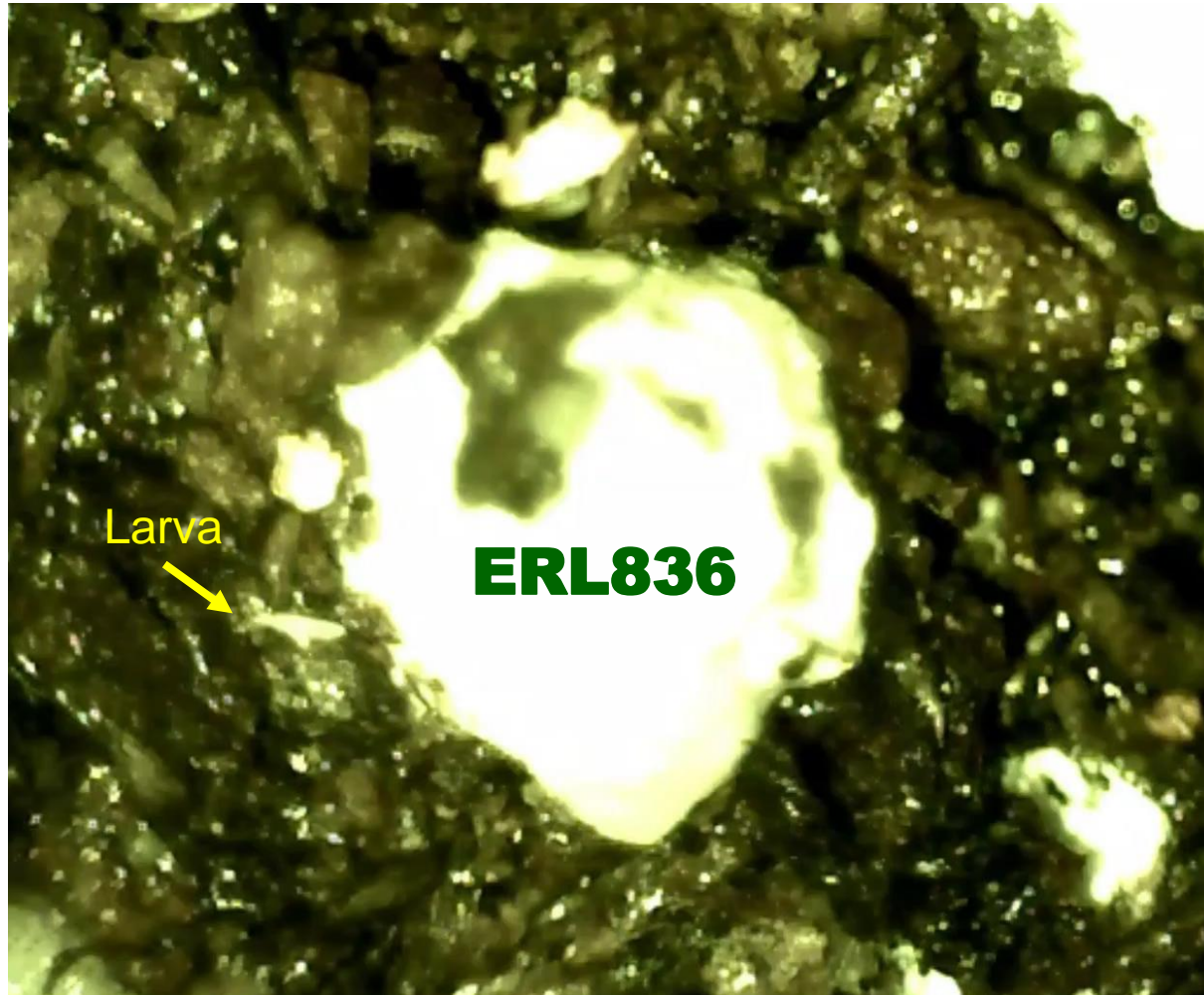
Trt No.	Treatment Name	Form Conc	Form Unit	Form Type	Rate Rate	Rate Unit	Application method	Control efficacy (%)
1	Control	-	-	-	-	-	-	[% live thrips = 839.5]
2	<i>Bb</i> ERL836	10 ⁷	conidia/g	GR	3	kg/10a	Soil application	91.3
4	<i>Bb</i> ERL1578	10 ⁷	conidia/g	GR	3	kg/10a	Soil application	93.0
6	Spinetoram (Chemical)	5	%	WG	0.5	g/L	Foliar application	85.5

No	Treatment	Form Conc	Form Unit	Form Type	Rate Rate	Rate Unit	Efficacy(%)	
							28 DAT	42 DAT
1	Check	-	-	-	-	-	-	-
2	ERL 836	2.5	%	GR	3	kg/10a	60.0	69.2
3	ERL 1578	2.5	%	GR	3	kg/10a	54.3	61.5
4	Clothianidin	1.8	%	GR	3	kg/10a	77.1	76.9

(Lee et al. 2017. BioControl)

Contact of ERL836 to thrips in soil

Application of ERL836: Soil application to control larvae and pupa



Field application of ERL836 GR in cucumber

GR application in farmer's field: Soil application after transplanting (to overcome resistance)



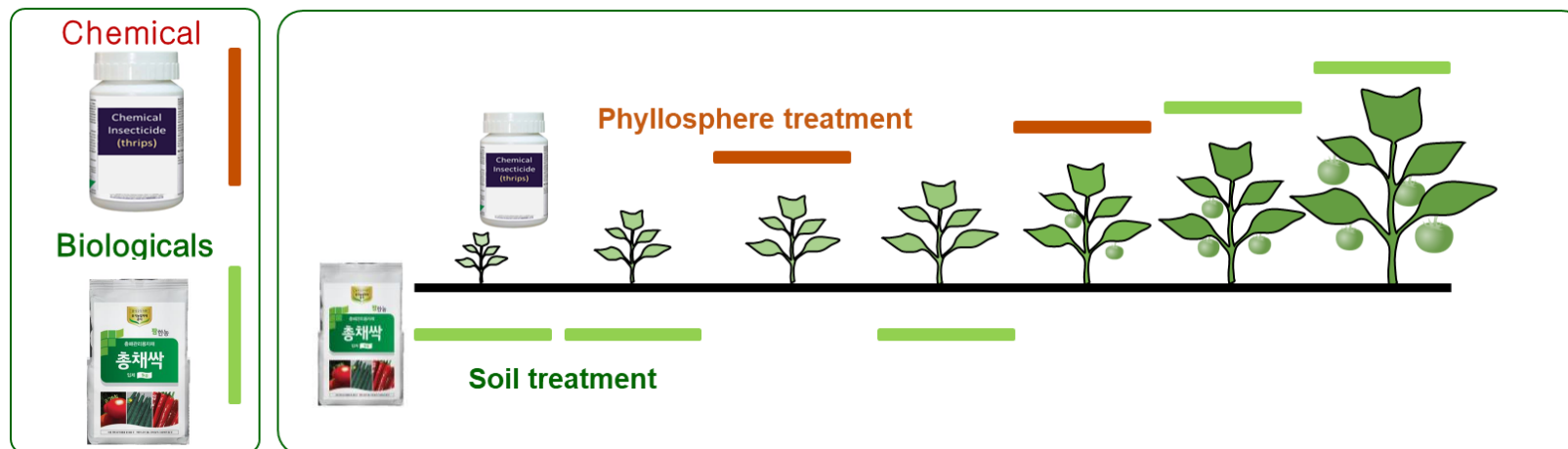
Interviewed by
Mi Rong Lee

Combinational application with chemicals

Combination with chemicals: Synergistic effect on both of chemicals and ERL836

- ✓ **Chemicals could be more easily penetrated to insect body** by the holes which were made by fungal hyphal penetration.
- ✓ **Insect-killing fungi could more easily penetrate hard and strong insect cuticles** because of the softened cuticles which was contributed by chemicals.
- ✓ Tank-mix or serial application of chemicals and biologicals could be very synergistic approach and reduce the amount of chemicals and overcome the residual issues in crop harvest.

(Lee et al., 2017. BioControl)



Storage stability of *B. bassiana* ERL836 (4 years)

Storage stability: At room temperature for four years

(Kim et al., 2019, J Asia-Pacific Entomol)



Active ingredient	Trade name	Country of the company	Formulation	Storage condition	Shelf life (months)	Reference website
<i>Beauveria bassiana</i>						
	Bassianil	Columbia	WP, 1x10 ⁹ CFU / g	≤ 24 °C	6	http://www.controlbiologico.com/
	Bassianil	Columbia	WP, 1×10 ⁹ CFU / g	4-10 °C	3	
	Bb Plus	South Africa	WP, 2×10 ¹⁰ CFU / g	4 °C	9	https://www.biocontrol.co.za/
	Bb Weevil	South Africa	Dusting powder, 2×10 ¹⁰ CFU / g	4 °C	9	https://www.biocontrol.co.za/
	Bea-Sin	Mexico	WP, 5×10 ⁹ CFU / g			
	Bibisav-2	Cuba	Bait composition, 1×10 ⁹ conidia / g	10-20 °C	3	
	Bio-Power	India	Liquid, 1×10 ⁹ CFU / ml	N/A	12	http://www.tstanes.com/
	BotaniGard® 22WP	USA	WP, 4.4 ×10 ¹⁰ spores / g	20-25 °C	12	https://www.bioworksinc.com/
	BotaniGard® ES	USA	ES, 2 ×10 ¹³ spores / ml	20-25 °C	18	https://www.bioworksinc.com/
	BotaniGard® MAXXX	USA	Emulsifiable dispersible oil, 1 ×10 ⁸ spores / ml	20-25 °C	12	https://www.bioworksinc.com/
	ChongchaeSak ERL836	Republic of Korea	Granules, > 1 × 10 ⁵ CFU / g	< 30 °C	24	http://www.farmhannong.com/
	Multiplex Baba	India	Liquid and powder, N/A	N/A	N/A	http://www.multiplexgroup.com/
	Mycotrol® ESO	USA	Liquid emulsifiable suspension, 2 ×10 ¹⁰ spores / ml	20-25 °C	18	https://www.bioworksinc.com/
	Mycotrol® WPO	USA	WP, 4.4 ×10 ¹⁰ spores / g	20-25 °C	12	https://www.bioworksinc.com/
	Naturalis-L®	USA	Oil dispersion formulation, 2 ×10 ⁷ CFU / ml	4-5 °C	12	http://belchim.co.uk/
	Probiobass	Bolivia	N/A	N/A	N/A	http://www.troybiosciences.com/
	Racer™	India	Powder, 1×10 ⁸ conidia / g	N/A	12	http://www.agrilife.in/
	Teraboveria	Guatemala	WP, N/A	20-25 °C	3	http://www.agricolaelsol.com/
<i>Beauveria brongniartii</i>						
	Beavaria brong	Italy	Barley kernels, 7.5 ×10 ⁹ conidia / g	2 °C	12	http://agrobionsa.anclastudio.com/
	Betel	France	Clay microgranules	N/A	N/A	
	Melocont® Pilzgerste	Austria	Barley kernels, 7.5 ×10 ⁹ conidia / g	2 °C	12	https://www.samen-schwarzenberger.at/home.html
<i>Cordyceps fumosorosea</i> (formerly <i>P. fumosoroseus</i>)						
	PreFeRal WG	Belgium	Water-dispersible granule, 2 ×10 ⁹ CFU / g	2-6 °C	6	https://www.biobestgroup.com/
<i>Lecanicillium</i> spp.						
	Mealikil® VL	India	WP, 1×10 ⁸ CFU / g		12	http://www.agrilife.in/
	Vertalec	The Netherlands	WP, 1×10 ⁹ blastospore / g	2-6 °C	6	
	Mycotal	The Netherlands	WP, 1×10 ¹⁰ CFU / g	2-6 °C	6	https://www.koppert.com/
<i>Metarhizium anisopliae</i>						
	BioCane™	Austria	Rice granules, 2×10 ⁹ conidia / g	5-10 °C	6	
	Met-92	Guatemala	WP, N/A	20-25 °C	3	
	Pacer®	India	WP, 1×10 ⁸ CFU / g		12	http://www.agrilife.in/

Commercial *B. bassiana* ERL836 GR & WP

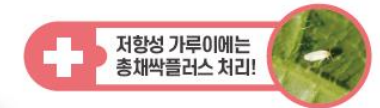
ERL836: GR-soil application at 3 kg/1,000 m² & WP-drenching 400 g/1,000 m²

- **Active ingredient** : *Beauveria bassiana* ERL 836 5% GR and 2.5% WP
- **Target Pest** : Thrips
- **Mode of Action** : Targeting pupal stage & hyphal attack and immune suppression
- **New concept of soil treatment product for controlling thrips**
 - After the soil treatment, control efficacy lasts >40 days by one time of application.
 - For effective control of thrips, pupae in soil should be contacted to the fungus.



정식 전부터 수확까지
간편하게 총채벌레 방제!

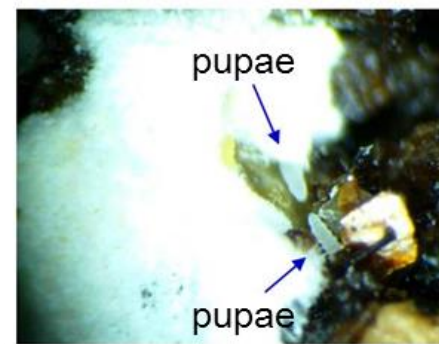
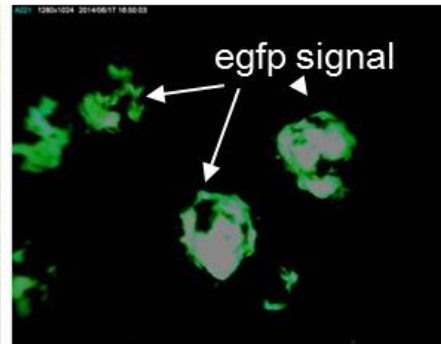
**총채벌레 전문
유기농업자재!**



Target Pest	Application time	Dose
Thrips Whitefly	GR: Soil application before transplanting WP: Soil drenching & Foliar spray	GR: 3 kg /1000 m² WP: Drenching 400 g/1000 m², Spray 1,000X



Bb-egfp granules in soil



Contact of thrips pupae to colonized *Bb*-egfp fungal mass in soil

Research publications for ERL86



Academic publications: virulence, production, stability, genome, RNA-seq & mode of action



Management of *Frankliniella occidentalis* (Thysanoptera: Thripidae) with granular formulations of entomopathogenic fungi

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HIGHLIGHTS

- Granular entomopathogenic fungi were tested in soil against western flower thrips.
- Experimental and registered bioactive strains were tested in cages in a greenhouse.
- Thrips damage was less on marigolds treated with experimental fungi than controls.
- Thrips numbers were less on marigolds treated with experimental fungi than controls.
- Experimental isolates outperformed the registered strain for managing thrips.

GRAPHICAL ABSTRACT

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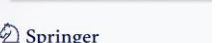
1. Introduction

Western flower thrips (WFT), *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) remains one of the most important pests of protected agriculture worldwide (Mound and Marullo, 1996; Berry, 1998; Montz et al., 2001). WFT feeds on a wide range of greenhouse ornamentals, causing cosmetic damage that reduces crop value. They also transmit plant viruses, which can destroy an entire crop if the pest is not controlled (Montz et al., 2004). Its cryptic behavior, rapid reproductive rate and resistance to many insecticides make WFT difficult to manage.

Entomopathogenic *Beauveria bassiana* granules to control soil-dwelling stage of western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae)

Se Jin Lee, Sihyeon Kim, Jong Cheol Kim, Mi Rong Lee, Muktaadir S. Hossain, Taek Su Shin, Tae Hoon Kim & Jae Su Kim

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Short communication
 Long-term storage stability of *Beauveria bassiana* ERL836 granules as fungal biopesticide

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Introduction

Chemical pesticides have been widely used to control insect pests and are among the most effective pest-management strategies in agriculture. However, they have been associated with negative impacts on human health, wildlife, and ecosystems. In addition, decades of resistance to chemical pesticides have led to the development of resistance among various pest species, decreasing their effectiveness (Osler et al., 2010). Regulations to reduce the overall use of chemical pesticides have prompted the development of alternative pest-management techniques. Interest in entomopathogens, including fungi, as resistance for biological pesticides is growing, and biopesticide share of the pesticide market is gradually increasing (Archer and Dara, 2010; de Faria and Vignati, 2007; Lacey et al., 2015).

Entomopathogenic fungi have been investigated as candidates for biological control against agricultural insect pests (Cecchi and Vasilev, 2015). Although there are numerous entomopathogenic fungi species, pest research and development efforts have focused largely on *Beauveria bassiana* (Deuteromycelium) (Hymenozozymales: Cordycepsiales), *Metarhizium anisopliae* (Zygomycota) (Hymenozozymales: Zygomycotales), and *Leucanidium leucoi* (Zygomycota) (Hymenozozymales: Cordycepsiales).

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Genomic Analysis of the Insect-Killing Fungus *Beauveria bassiana* JEF-007 as a Biopesticide

Se Jin Lee¹, Mi Rong Lee¹, Sihyeon Kim¹, Jong Cheol Kim¹, So Eun Park¹, Dongwei Lu², Tae Young Shin¹, Yu-Shin Nam³ & Jae Su Kim^{1*}

Insect-killing fungi have high potential in pest management. A deeper insight into the fungal genes at the whole genome level is necessary to understand the intra-specific or intra-species genetic diversity of fungal genes, and to select excellent isolates. In this work, we conducted a whole genome sequencing of the entomopathogenic fungus *Beauveria bassiana* (JEF-007) characterized pathogenesis-related features and compared with other isolates including BR-AR558F2806. A large number of BR-JEF-007 genes showed high identity with BR-AR558F2806, but some genes showed moderate or low identity. The two BR isolates showed a significant difference in vegetative growth, antibiotic susceptibility, and virulence against *Tenebrio molitor* larvae. When highly identical genes between the two BR isolates were subjected to real-time PCR, their transcription levels were different, particularly in heat shock protein 70 and 90 genes which are related to conidial thermotolerance. In several *B. bassiana* isolates, a ribonuclease and trypan-blue protease genes involved in pathogenesis were highly conserved, but other genes showed remarkable sequence

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scientific reports

OPEN Gene diversity explains variation in biological features of insect killing fungus, *Beauveria bassiana*

Laila Gasm¹, Sehyeon Bae¹, Jong Cheol Kim¹, Sihyeon Kim¹, Mi Rong Lee¹, So Eun Park¹, Tae Young Shin¹, Se Jin Lee¹, Bruce L. Parker⁴ & Jae Su Kim^{1,2*}

Beauveria bassiana is a species complex whose isolates show considerable natural genetic variability. However, little is known about how this genetic diversity affects the fungus performance. Herein, we characterized the diversity of genes involved in various mechanisms of the infective cycle of 42 isolates that have different growth rates, thermotolerance and virulence. The analyzed genes showed general genetic diversity measured as non-synonymous changes (NSC) and copy number variation (CNV), with most of them being subjected to positive episodic diversifying selection. Correlation analyses between NSC or CNV and the isolate virulence, thermotolerance and growth rate revealed that various genes shaped the biological features of the fungus. Lectin-like, mucin signaling, biotrophy associated and chitinase genes NSCs correlated with the three biological features of *B. bassiana*. In addition, other genes (i.e. DNA photolyase and cyclophilin B) that had relatively conserved sequences, had variable CNV across the isolates which were correlated with the variability of other variables or thermotolerance of *B. bassiana* isolates. The data obtained is important for a better understanding of population structure, ecological and potential impact when isolates are used as mycoinsecticides and

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RESEARCH ARTICLE

Management of overwintering pine sawyer beetle, *Monochamus alternatus* with colonized *Beauveria bassiana* ERL836

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ABSTRACT

Background: Insect-killing fungal species, *Beauveria bassiana*, is an environment-friendly pest management tool, and many isolates are on the track of industrialization. However, some of *B. bassiana* isolates show similar morphology and virulence against insect pests, and so it is hard to differentiate them. Herein we used two patented isolates, ERL836 and JEF-007, and investigated their virulence against western flower thrips, *Frankliniella occidentalis*, and further analyzed genome structures and transcriptional responses when interacting with cuticles of thrips to see possible differences on the initial step of fungal infection.

Results: The two isolates showed no significant differences in fungal growth, conidial production, and virulence against thrips, and they were structurally similar in genome. But, in transcription level, ERL836 appeared to infect thrips easily, while JEF-007 appeared to have more difficulty. In the GO analysis of ERL836 differentially expressed genes, the number of up-regulated genes was much larger than that of down-regulated genes, when compared to JEF-007 DEGs (more genes down-regulated). Interestingly, in the enrichment analysis using shared DEGs between two infecting isolates, plasma membrane-mediated transport activity and fatty acid degradation pathway including cytochrome P450 were more active in infecting ERL836.

Conclusions: The two *B. bassiana* isolates had similar morphology and virulence as well as genome structure, but in transcription level they differently interacted with the cuticle of western flower thrips. This comparative approach using shared DEG analysis could be easily applied to characterize the difference of two *B. bassiana* isolates, JEF-007 and ERL836.

Keywords: *Beauveria bassiana*, Western flower thrips, Genome, Transcription, Cytochrome P450



Beauveria bassiana is a species complex whose isolates show considerable natural genetic variability. However, little is known about how this genetic diversity affects the fungus performance. Herein, we characterized the diversity of genes involved in various mechanisms of the infective cycle of 42 isolates that have different growth rates, thermotolerance and virulence. The analyzed genes showed general genetic diversity measured as non-synonymous changes (NSC) and copy number variation (CNV), with most of them being subjected to positive episodic diversifying selection. Correlation analyses between NSC or CNV and the isolate virulence, thermotolerance and growth rate revealed that various genes shaped the biological features of the fungus. Lectin-like, mucin signaling, biotrophy associated and chitinase genes NSCs correlated with the three biological features of *B. bassiana*. In addition, other genes (i.e. DNA photolyase and cyclophilin B) that had relatively conserved sequences, had variable CNV across the isolates which were correlated with the variability of other variables or thermotolerance of *B. bassiana* isolates. The data obtained is important for a better understanding of population structure, ecological and potential impact when isolates are used as mycoinsecticides and

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RESEARCH ARTICLE

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Margaret et al., 2012. **Biological Control**
 Lee et al., 2017. **BioControl**
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 Kim et al., 2019. **J Asia-Pacific Entomol**
 Kim et al., 2020. **BMC Genomics**
 Gasm et al., 2021. **Scientific Report**
 Kim et al., 2022. **PLOS ONE**

Industrialization of ERL836 and reputation

Industrialization in Korea



Successful launching in Korean local market, 2017 and now MS No. 1 in Korea
Farmers' favorable review
Release ERL836 WP 2020



Launching GR (2017, Korea)
WP (2020, Korea)

Award of National Medal (2018)

→ Jae Su Kim's lab (Jeonbuk National University)



Jeonbuk National University, University of Vermont, and FarmHannong
Student training at Jeonbuk National University

→ Test in Japan showed excellent performance (2023, Japan)
(under discussion of registration in Japan)

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