The coffee berry borer: a short review with recent findings and future research directions

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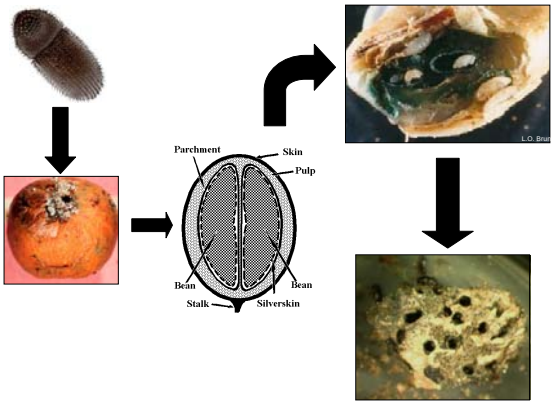
Coffee berry borer – *Hypothenemus hampei*

Photo by Peggy Greb, USDA, Agricultural Research Service

Damage



CBB infestation levels

- **Up to 60% in Colombia**
- **58-75% in Jamaica**
- **80% in Uganda**
- **50-80% in Côte d'Ivoire**

Estimated losses

> $500 MILLION!

Coffee berry borer

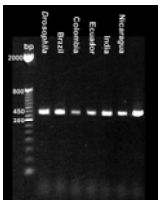

Egg

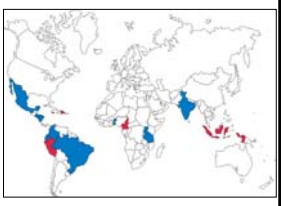

Larva


Pupa

Wolbachia infection

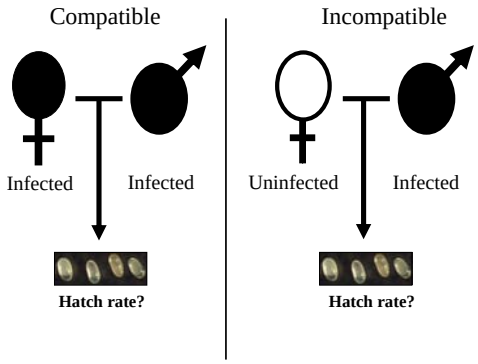
- FEMALE-BIASED SEX RATIOS





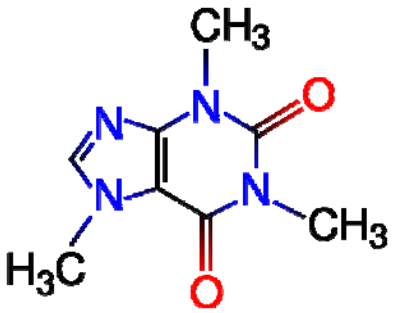
Vega et al., Annals of the Entomological Society of America 95:374-378

Cytoplasmic Incompatibility



- **How many *Wolbachia* strains exist in the CBB?**
- **Frequencies and distribution?**
- **Can we manipulate *Wolbachia* to reduce the number of female progeny?**

Caffeine



CBB-associated yeasts

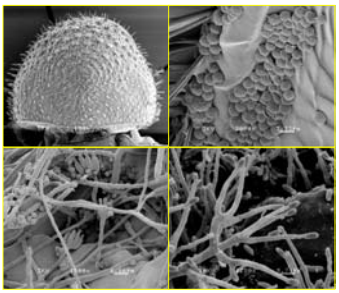
Pichia burtonii and *Candida fermentati*

Vega et al., Entomologia Experimentalis et Applicata 107:19-29

➢ **How does the CBB breaks down caffeine?**

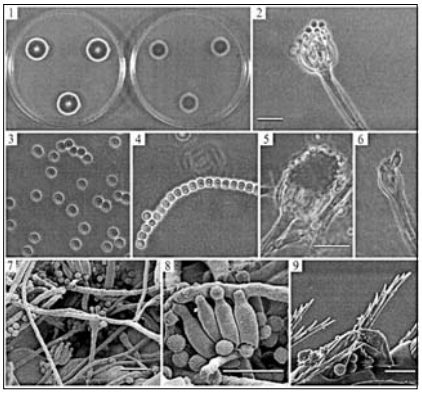
Fungi associated with the CBB in Mexico

✓ 40 fungal species in 22 genera



Pérez *et al.*, *Mycological Research* 107:879-887

Penicillium brocae, a new species associated with the CBB in Chiapas, Mexico

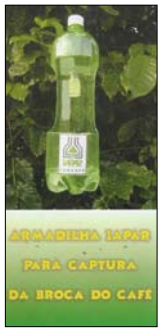


Peterson *et al.*, Mycologia 95:141-147

➢ **How does the CBB fungal diversity differs among countries?**

➢ **Is there a common denominator among this fungal diversity?**

Attractants



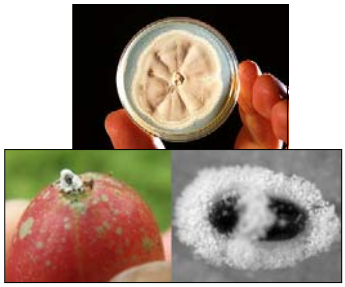
compound	t_R	green	half-ripe	ripe	overripe
1,3-butadiene, 2-methyl-	2.68				1839
unknown	3.04	160	97		1529
acetaldehyde	3.45	1027	2201	3017	8731
octane	5.06	282	138	70	396
propanal, 2-methyl-	6.23			170	9831
2-propanone	6.42	353	711	1289	789
methyl acetate	6.85		89	125	193375
furan, 3-methyl-	8.23		155	160	207
nonane	8.39	703	231	207	541
acetic acid, ethyl ester	8.84	115	2372	1846	853170
furan, 2-methyl-	9.07	7361	4573	1331	3987
unknown	9.28	159	210	1245	3040
unknown	9.45				589
propanal, 2,2-dimethyl-	9.64				488
butanal, 3-methyl	9.80		34	75	738
propanoic acid, 2-methyl-, methyl ester	9.95				313
ethanol	10.56	39055	289641	308099	437377
unknown	11.00		331		252
propanoic acid, ethyl ester	11.14			44	1658
propanoic acid, 2-methyl ethyl ester	11.34				856
acetic acid, propyl ester	11.70	46			5050
2-butanone, 3-methyl-	11.94	487	149	3487	53753
acetic acid, 2-methylpropyl ester	12.89			258	364014
1-propanol	13.65	86	1121	1896	9495
toluene	13.85	51	102	195	376
2-butenal	14.03			72	132
acetic acid, butyl ester	14.61				1071
disulfide, dimethyl-	14.88	390	593	256	138
1-propanol, 2-methyl-	15.11	106	138	5507	281861
2-butenal, 2-methyl-	15.54		102	43	513
2-pentanol	15.80			77	535
1-butanol, 3-methyl-, acetate	15.97				23299
1-butanol	16.49	64	162	316	1800
O-xylene	16.71	30	46	106	98
1-hexene-3-ol	16.86	56	83	112	578
β-myrcene	16.92	112	73	154	593
1-phellandrene	17.16				196
acid acetic, pentyl ester	17.28				91
α-terpinene	17.53				252
2-heptanone	17.66			79	1703
isoamyl alcohol	18.02	258	371	582	31265
3-pentanol, 2-methyl-	18.39				211
β-ocimene	18.68		32	58	614
1-pentanol	19.03				153
1,3,7-octatriene, 3,7-dimethyl	19.12		46	107	867
3-octanone	19.35	155	76	77	1194
styrene	19.64				4270
(+)-2-carene	20.06				168
unknown	20.21	29	120	100	892
3-hydroxy-2-butanone	20.40				54001
heptanol	20.48	16	27	98	2052
cyclopentanol, 2-methyl, trans	20.64			49	200
2-buten-1-ol, 2-methyl-	20.71				135
3-ethyl, 2-pentanol	21.14				156
hexanol	21.28	301	81	175	6530
aninole	21.60		151	199	470
3-hexen-1-ol, formate	22.05	59	59	120	385
butanol, 3-methyl-, acetate	22.15				462
3-ethyl, 4-methylpentas-1-ol	22.40				535
pentanol, 3,4-dimethyl-	22.77			34	181
1-octen-3-ol	23.19				441
acetic acid	23.39				53452
benzene, 1-methoxy-3-methyl	23.68	32	243	168	859
formic acid, octyl ester	24.49			35	908
unknown	25.08				157
unknown	25.50				376
propanedioic acid, dimethyl-	25.58				1109
total area counts		51494	304560	332035	2427296
no. of compounds		27	34	41	68

Ortiz *et al.*, *Journal of Agricultural and Food Chemistry* 52:5914-5918

- **Can we develop better CBB attractants?**
- **Can we develop CBB repellents?**

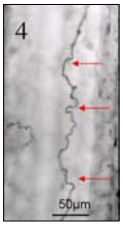
Control

Natural enemies: fungal insect pathogens

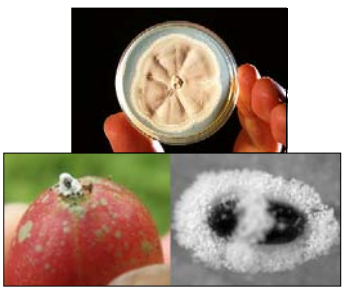


Beauveria bassiana

Endophytes



Fungal hyphae in leaves

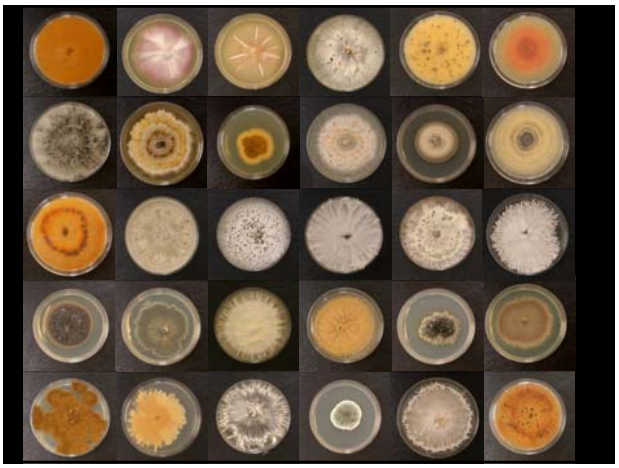


Beauveria bassiana

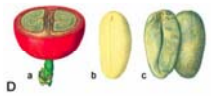
Beauveria bassiana recovery:

MONTHS POST-INOCULATION	% RECOVERY
2	31
4	5.5
6	2.7
8	0

Posada *et al*., *Mycological Research* 111:748-757



Fungal endophytes in green coffee seeds



Fungal id	Country
Acremonium sp.	Puerto Rico
Aspergillus sumatrense	Puerto Rico
Aspergillus fumigatus	India
Aspergillus fumigatus	Vietnam
Aspergillus niger	Vietnam
Aspergillus pseudodeflectus	Papua New Guinea
Aspergillus pseudodeflectus	Vietnam
Aspergillus tubingiensis	Colombia
Aspergillus tubingiensis	Kenya
Clavicipitaceae sp. 1	Puerto Rico
Clavicipitaceae sp. 2	Puerto Rico
Aspergillus (Eurotium) ruber	India
Fusarium solani complex	Vietnam
Gibberella sp.	Colombia
Penicillium sp., subgenus *Biverticillium*	India
Penicillium crustosum	Guatemala
Penicillium olsonii	Colombia

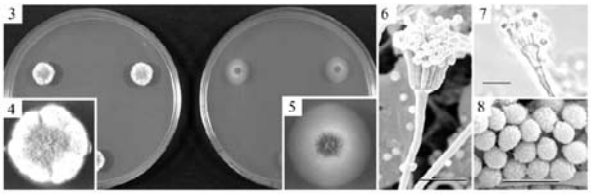
Vega *et al*., *Mycosystema* 27:75-84

Fungal endophytes in coffee seedlings

Alternaria sp.	Hypocreales sp.
Arthopyrenaceae	*Macrophomina* sp.
Aspergillus tamari	*Paecilomyces* sp.
Aspergillus westerdijkiae	*Penicillim citrinum*
Beauveria bassiana	*Penicillium brevicompactum*
Bionectriaceae	*Penicillium cecidicola*
Chaetomium sp.	*Penicillium glabrum*
Cladosporium cf. *sphaerospermum*	*Penicillium janthinellum*
Clavicipitaceae	*Penicillium* sp. near *daleae*
Colletotrichum gloeosporoides complex	*Penicillium steckii*
Cylindrocarpon sp.	*Penicillium toxicarium*
Exobasidiomycetidae	Phyllachoraceae
Exophiala sp.	*Plectosphaerella* sp.
Fusarium cf. *oxysporum* f. sp. *vasinfectum*	*Pleosporales* sp.
Fusarium oxysporum complex (1)	*Pseudallescheria* cf. *boydii*
Fusarium oxysporum complex (2)	*Rhizopycnis* sp.
Fusarium sp. (1)	*Trichoderma* sp.
Fusarium sp. (2)	*Trichoderma hamatum*
Fusarium sp. (Lateritium clade 1)	*Trichoderma harzianum*

Posada *et al*., *Mycological Research* 111:748-757

Penicillium coffea, a new endophytic species isolated from a coffee plant



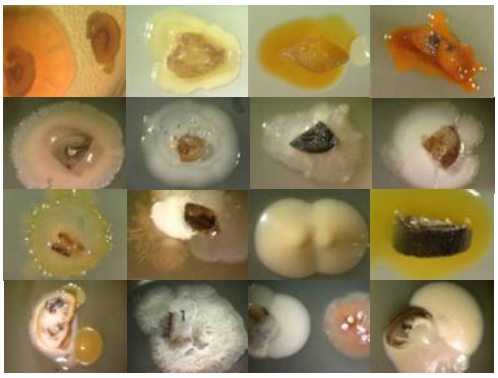
Peterson *et al*., *Mycologia* 97:659-666

Penicillium species endophytic in coffee plants and ochratoxin A production

- brevicompactum*
- *brocae*
- *cecidicola*
- *citrinum*
- *coffeae*
- crustosum*
- *janthinellum*
- olsonii*
- oxalicum*
- *sclerotiorum*
- *steckii*
- *near diversum*
- *near roseopurpureum*

Vega *et al*., *Mycologia* 98:31-42

Coffee bacterial endophytes



Vega et al., Journal of Basic Microbiology 45:371-380

Coffee bacterial endophytes

Bacillus cereus	***Gordona* sp.**
Bacillus megaterium	***Klebsiella planticola***
Bacilus subtilis	***Klebsiella pneumoniae***
Bacillus megaterium	***Klebsiella trevisanii***
Burkholderia cepacia	***Kocuria kristinae***
Burkholderia gladioli	***Methylobacterium radiotolerans***
Burholderia glathei	***Micrococcus* sp.**
Burkholderia pyrrocina	***Pantoea agglomerans***
Cedecea davisae	***Pseudomonas chloroaphis***
***Chromobacterium* sp.**	***Pseudomonas putida***
Clavibacter michiganense insidiosum	***Rhodococcus equi***
Curtobacterium flaccumfaciens	***Salmonella typhimurium***
Enterobacter asburiae	***Serratia liquefaciens***
Enterobacter cancerogenus	***Stenotrophomonas maltophila***
Enterobacter gergoviae	***Variovorax paradoxus***
Escherichia vulneris	***Xanthomonas* sp.**

Vega et al., Journal of Basic Microbiology 45:371-380

➢ What roles could endophytes be playing?

➢ Can we establish fungal insect pathogens as systemic endophytes?

Summary

✓ *Wolbachia*

✓ Caffeine

✓ Fungi associated with the CBB

✓ Attractants

✓ Endophytes

- Introducing fungal insect pathogens
- Fungal endophyte biodiversity
- Bacterial endophytes

Natural enemies

✓ In addition to fungi, are there viruses, bacteria, or protozoa that might have a negative effect on the CBB?

✓ Parasitoids, predators – Juliana Jaramillo

✓ Nematodes – Francisco Infante

Special thanks to the International Coffee Organization for organizing this seminar, and for inviting me to participate.

Note: Papers cited in this talk can be downloaded at: http://www.ars.usda.gov/pandp/docs.htm?docid=13128