Prospects for biological control of Sclerotinia head rot in confection sunflowers with honeybee-vectored *Clonostachys rosea:* **conclusions from multi-year, multi-location research**

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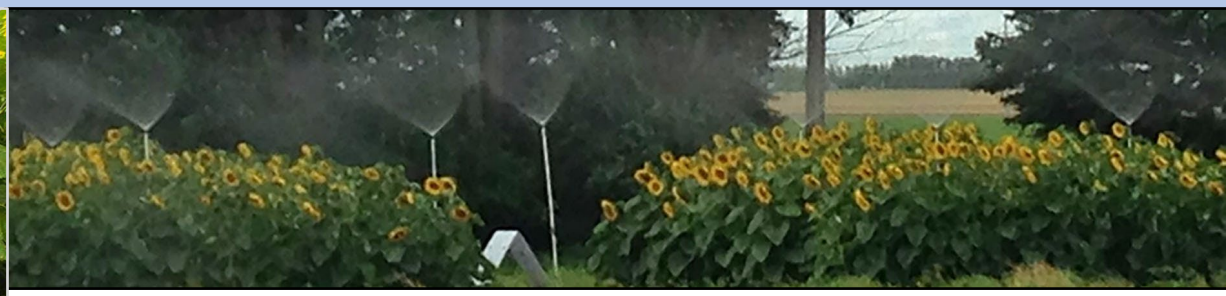
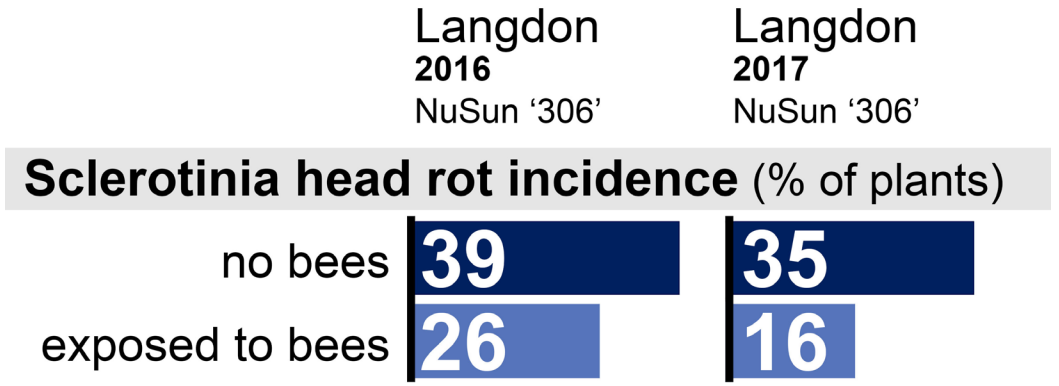
Preliminary testing, 2016-2017
Oilseed sunflowers, bumble-vectored *Clonostachys rosea*

Non-replicated studies. Sunflowers exposed to bees were **spatially separated** from identically managed sunflowers not exposed to bees.
Langdon, ND (2016, 2017)



Sunflowers were inoculated twice:
- Once at approx. R5.4-R5.6
- Once at approx. R5.5-R5.9

To each head, 15,000 ascospores were applied per head per inoculation (delivered with a hand-held spray bottle calibrated to deliver 5,000 spores per spray).



Preliminary testing (2017, 2019) – Non-oil sunflowers, honeybee-vectored *Clonostachys rosea*

Replicated studies (4-5 reps). **Bees were excluded** from sunflower heads in the non-treated control **by placing perforated pollination bags over heads**. Heads were bagged from bloom initiation to R7. *Carrington, ND (2017, 2019)*

	Carrington **2018** NuSeed 'Jaguar'	Carrington **2019** NuSeed 'Jaguar'
Sclerotinia head rot incidence (% of plants)		
bagged heads	70 b	93 a
unbagged heads	34 a	69 a
	CV: 16.0	CV: 9.4
Sunflower yield (pounds/acre)		
bagged heads	635 b	NO DATA
unbagged heads	1607 a	
	CV: 9.4	

INOCULATIONS:

- Sunflowers were inoculated twice in 2018 (at R5.5 and R5.8-R5.9) and once in 2019 (at R5.7-R5.9).
- To each head, 15,000 ascospores were applied per head per inoculation (delivered with hand-held spray bottle calibrated to deliver 5,000 spores / spray).

POLLINATION BAGS:

18 x 16 inch (length x width) pollination bags made of fine mesh fabric with 1 mm x 1 mm holes (Lawson Bags; Northfield, IL)

Strip studies (2020-2023) Response to bees and bee-vectored *C. rosea* relative to distance from the bee hive

- Replicated studies (3 reps).
- Sunflowers established in a strip 60-110 ft wide by 2,200-2,600 ft long
- Bee hives placed at one end and two-thirds the distance along the strip
- Response to bees, bee-vectored *C. rosea* assessed at 3, 4 or 5 distances from the hives.
- Response to bees, bee-vectored *C. rosea* assessed on sunflowers inoculated with lab-generated ascospores of *S. sclerotiorum* and on non-inoculated sunflowers
- Sunflowers excluded from the control with pollinator-exclusion bags made of mesh or highly perforated plastic
- Plot sizes large (average 99 plants/plot) for rigorous assessment of disease & yield
- Testing in Carrington, on-farm site in Wells County, on-farm site in Cavalier County

Impact of the bags on disease development in the absence of introduced bees, bee-vectored biological control (2022-2023)

- 1 study in Carrington, 1 study in Langdon in 2022
- 3 studies planted approx. 1 week apart in Carrington in 2023
- Replicated studies (4 to 7 reps)
- All three types of pollinator-exclusion bags utilized in this project tested
- Plot sizes large (average 178 plants/plot) for rigorous assessment of disease & yield

Reduction in disease observed in Sclerotinia-inoculated sunflowers exposed to bees and bee-vectored biological control:

	Average across all studies
Sclerotinia head rot incidence (%)	
exposed to bees, *inoculated with pathogen*	**24** a
bees excluded, *inoculated with pathogen*	**44** b
F, *P*>*F*:	46.52, < 0.0001
CV:	22.2

46% reduction

location of study (county)	Foster	Foster	Cavalier	Wells	Foster	Cavalier	Foster	Foster	Cavalier	Foster	Foster	Cavalier	Cavalier
year	2023	2022	2022	2021	2021	2021	2020	2020	2020	2019	2018	2017	2016
number of distances evaluated	3	4	4	4	4	5	5	5	5	1	1	1	1
type of bee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	bumblebee	bumblebee
market class	confection	confection	confection	confection	confection	confection	confection	confection	confection	confection	confection	oilseed	oilseed
Sclerotinia head rot incidence (%)													
exposed to bees, *inoculated with pathogen*	**41** b	**28** b	**12**	**23** b	**4** b	**27** b	**22** b	**17** b‡	**9** a*	**69** a	**16** a	**16**	**26**
bees excluded, *inoculated with pathogen*	**63** c	**44** b	**35**	**70** c	**8** b	**41** b	**47** c	**45** c	**16** a	**93** a	**35** b	**35**	**39**
exposed to bees, no pathogen inoculation	**1** a	**1** a	**1**	**0.1** a	**0.2** a	**4** a	**2** a	**1** a	**14** a	NO DATA	NO DATA	NO DATA	NO DATA
bees excluded, no pathogen inoculation	**1** a	**0** a	**2**	**0.2** a	**0.3** a	**0** a	**1** a	**2** a	**10** a	NO DATA	NO DATA	NO DATA	NO DATA
F, *P*>*F*:	172.85, < 0.0001	28.43, < 0.0001		923.10, < 0.0001	29.93, < 0.0001	108.56, < 0.0001	119.21, < 0.0001	71.93, < 0.0001	1.75, 0.1787	15.04, 0.0605	43.05, 0.0028	non-replicated study	non-replicated study
CV:	24.6	54.4		12.9	64.0	32.7	31.8	39.3	84.3	9.4	16.0		

Impact of pollinator-exclusion bags on disease: Impact of leaving heads unbagged in studies with no introduced bees or bee-vectored biocontrol

location of study	**Carrington**	**Langdon**	**Carrington** June 1 plant date	**Carrington** June 7 plant date	**Carrington** June 12 plant date	Average across studies
year	2022	2022	2023	2023	2023	
Sclerotinia head rot incidence (%)						
Unbagged heads	**7** b*	**5** a*	**84** a	**63** a	**41** a	**40** a
HDPE bag[1] (used in 2020-2021)	**26** a	**9** a	**85** a	**72** ab	**65** b	**51** ab
Monofilament bag[1] (used in 2022-2023)	**35** a	**9** a	**85** a	**80** b	**61** b	**54** b
F, *P*>*F*:	18.57, < 0.0001	1.8, 0.2154	0.1, 0.9592	8.03, 0.0083	67.23, < 0.0001	6.72, 0.0194
CV:	30.6	55.2	5.6	10.7	5.6	13.4

IMPACT OF LEAVING HEADS UNBAGGED:

22 to 26% reduction in disease

[1] **Type of pollinator-exclusion bag used. HDPE:** 16 x 18 in. (40.64 x 45.72 cm) perforated HDPE plastic bags with a 336-micron pore diameter and 24% of the surface open (Midco Global; Kirkwood, MO). **Monofilament:** 15.5 x 30 in. (39.4 x 26.2 cm) monofilament mesh bags with 2.5 mm x 1 mm holes (Midco Global; Kirkwood, MO).

Reduction in disease observed in Sclerotinia-inoculated sunflowers exposed to bees and bee-vectored biological control:

	Average across all studies
Sclerotinia head rot severity index (%)	
exposed to bees, *inoculated with pathogen*	**20** a
bees excluded, *inoculated with pathogen*	**41** b
F, *P*>*F*:	29.68, 0.0003
CV:	28.9

50% reduction

location of study (county)	Foster	Foster	Cavalier	Wells	Foster	Cavalier	Foster	Foster	Cavalier	Foster	Foster	Cavalier	Cavalier
year	2023	2022	2022	2021	2021	2021	2020	2020	2020	2019	2018	2017	2016
number of distances evaluated	3	4	4	4	4	5	5	5	5	1	1	1	1
type of bee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	bumblebee	bumblebee
market class	confection	confection	confection	confection	confection	confection	confection	confection	confection	confection	confection	oilseed	oilseed
Sclerotinia head rot severity index (%)													
exposed to bees, *inoculated with pathogen*	**39** b	**27** b	**8**	**23** b	**4** b	**27** b	**21** b	**16** b*‡	NO DATA	NO DATA	**35** a*	**5**	**20**
bees excluded, *inoculated with pathogen*	**62** c	**43** b	**28**	**69** c	**7** c	**41** b	**47** c	**44** c	NO DATA	NO DATA	**70** b	**12**	**31**
exposed to bees, no pathogen inoculation	**0.5** a	**0.4** a	**0.4**	**0.1** a	**0.2** a	**3.7** a	**1.6** a	**1.2** a	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
bees excluded, no pathogen inoculation	**0.7** a	**0.3** a	**1.2**	**0.2** a	**0.2** a	**0.5** a	**0.5** a	**0.7** a	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
F, *P*>*F*:	176.66, < 0.0001	39.58, < 0.0001		913.93, < 0.0001	31.61, < 0.0001	107.78, < 0.0001	121.93, < 0.0001	101.08, < 0.0001			44.19, 0.0027	non-replicated study	non-replicated study
CV:	24.5	48.0		13.0	62.9	32.9	31.7	37.3			15.9		

Impact of pollinator-exclusion bags on disease: Impact of leaving heads unbagged in studies with no introduced bees or bee-vectored biocontrol

location of study	Carrington	Langdon	Carrington June 1 plant date	Carrington June 7 plant date	Carrington June 12 plant date	Average across studies
year	2022	2022	2023	2023	2023	
Sclerotinia head rot severity index (%)						
Unbagged heads	**7** b*	**4** a*	**82** a	**62** b	**41** a	**39** a
HDPE bag[1] (used in 2020-2021)	**25** a	**6** a	**80** a	**71** ab	**64** b	**49** ab
Monofilament bag[1] (used in 2022-2023)	**33** a	**7** a	**83** a	**80** a	**59** b	**53** b
F, *P*>*F*:	17.77, < 0.0001	1.3, 0.0362	0.4, 0.7561	8.48, 0.0070	59.48, 0.0001	5.75, 0.0283
CV:	31.4	53.8	5.6	10.6	5.8	14.0

IMPACT OF LEAVING HEADS UNBAGGED:

21 to 26% reduction in disease

[1] **Type of pollinator-exclusion bag used. HDPE:** 16 x 18 in. (40.64 x 45.72 cm) perforated HDPE plastic bags with a 336-micron pore diameter and 24% of the surface open (Midco Global; Kirkwood, MO). **Monofilament:** 15.5 x 30 in. (39.4 x 26.2 cm) monofilament mesh bags with 2.5 mm x 1 mm holes (Midco Global; Kirkwood, MO).

Reduction in disease observed in Sclerotinia-inoculated sunflowers exposed to bees and bee-vectored biological control:

	Average across all studies
Sclerotia contamination of grain (%)	
exposed to bees, *inoculated with pathogen*	**2.1** a
bees excluded, *inoculated with pathogen*	**5.4** b
F, *P*>*F*:	19.53, < 0.0001
CV:	75.7

61% reduction

location of study (county)	Foster	Foster	Cavalier	Wells	Foster	Cavalier	Foster	Foster	Cavalier	Foster	Foster	Cavalier	Cavalier
year	2023	2022	2022	2021	2021	2021	2020	2020	2020	2019	2018	2017	2016
number of distances evaluated	3	4	4	4	4	5	5	5	5	1	1	1	1
type of bee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	bumblebee	bumblebee
market class	confection	confection	confection	confection	confection	confection	confection	confection	confection	confection	confection	oilseed	oilseed
Sclerotia contamination of grain (% by weight)													
exposed to bees, *inoculated with pathogen*	**3.6** b*‡	**2.7** b	**0.2**	**2.3** b	**0.6** b	**0.8** a	**3.3** b	**3.1** b*‡	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
bees excluded, *inoculated with pathogen*	**4.3** b	**6.4** b	**1.2**	**9.3** c	**0.6** b	**7.9** b	**7.4** c	**6.1** c	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
exposed to bees, no pathogen inoculation	**0.1** a	**0.0** a	**0.0**	**0.3** a	**0.2** ab	**0.7** a	**0.5** a	**0.9** a	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
bees excluded, no pathogen inoculation	**0.0** a	**0.1** a	**0.0**	**0.4** a	**0.1** a	**0.4** a	**0.6** a	**0.6** a	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
F, *P*>*F*:	110.78, < 0.0001	12.93, < 0.0001		102.27 < 0.0001	5.64, 0.0045	24.76, < 0.0001	84.73, < 0.0001	53.10, < 0.0001					
CV:	26.8	95.9		34.3	107.3	86.7	33.5	35.0					

Impact of pollinator-exclusion bags on disease: Impact of leaving heads unbagged in studies with no introduced bees or bee-vectored biocontrol

location of study	**Carrington**	**Langdon**	**Carrington** June 1 plant date	**Carrington** June 7 plant date	**Carrington** June 12 plant date	Average across studies
year	2022	2022	2023	2023	2023	
	Sclerotia contamination (% by weight)					
Unbagged heads	**1.1** b*	NO DATA	**10.7** ab	**8.9** a	**3.8** a	**6.1** a
HDPE bag[1] (used in 2020-2021)	**2.6** a	NO DATA	**12.7** b	**10.9** a	**3.6** a	**7.4** a
Monofilament bag[1] (used in 2022-2023)	**3.8** a	NO DATA	**12.5** b	**13.1** a	**2.9** a	**8.1** a
F, *P*>*F*:	12.7, 0.0001		8.94, 0.0046	1.82, 0.2121	0.34, 0.7322	3.02, 0.1236
CV:	21.5		16.3	35.4	42.2	15.7

IMPACT OF LEAVING HEADS UNBAGGED:

18 to 24% reduction in disease

[1] **Type of pollinator-exclusion bag used. HDPE:** 16 x 18 in. (40.64 x 45.72 cm) perforated HDPE plastic bags with a 336-micron pore diameter and 24% of the surface open (Midco Global; Kirkwood, MO). **Monofilament:** 15.5 x 30 in. (39.4 x 26.2 cm) monofilament mesh bags with 2.5 mm x 1 mm holes (Midco Global; Kirkwood, MO).

Increase in yield observed in Sclerotinia-inoculated sunflowers exposed to bees and bee-vectored biological control:

	Average across all studies
	Yield (lbs/ac)
exposed to bees, *inoculated with pathogen*	**1831** a
bees excluded, *inoculated with pathogen*	**1607** a
F, *P*>*F*:	4.05, 0.0718
CV:	15.2

14% increase

location of study (county)	Foster	Foster	Cavalier	Wells	Foster	Cavalier	Foster	Foster	Cavalier	Foster	Foster	Cavalier	Cavalier
year	2023	2022	2022	2021	2021	2021	2020	2020	2020	2019	2018	2017	2016
number of distances evaluated	3	4	4	4	4	5	5	5	5	1	1	1	1
type of bee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	bumblebee	bumblebee
market class	confection	confection	confection	confection	confection	confection	confection	confection	confection	confection	confection	oilseed	oilseed
	Yield (lbs/ac)												
exposed to bees, *inoculated with pathogen*	**1047** b	**2320** a		**2872** a*	**1313** a	**1892** b	**2001** a	**1904** a*	**1376** a*	NO DATA	**1607** a*	**1761**	**2053**
bees excluded, *inoculated with pathogen*	**1449** ab	**1892** b		**2295** b	**1267** a	**1637** b	**1737** b	**1666** b	**1243** a	NO DATA	**635** b	**1981**	**1880**
exposed to bees, no pathogen inoculation	**1723** a	**2190** ab		**2967** a	**1426** a	**2793** a	**2155** a	**1942** a	**1288** a	NO DATA	NO DATA	NO DATA	NO DATA
bees excluded, no pathogen inoculation	**1595** a	**2163** ab		**2869** a	**1320** a	**2458** a	**2058** a	**1967** a	**1331** a	NO DATA	NO DATA	NO DATA	NO DATA
F, *P*>*F*:	5.52, 0.0094	3.89, 0.0264		13.34, < 0.0001	2.94, 0.0536	24.24, < 0.0001	10.34, < 0.0001	11.32, < 0.0001	1.38, 0.2687		102.44, 0.0005	non-replicated study	non-replicated study
CV:	23.9	12.8		10.6	10.2	18.8	10.9	8.5	14.4		6.3		

Impact of pollinator-exclusion bags on disease: Impact of leaving heads unbagged in studies with no introduced bees or bee-vectored biocontrol

location of study	Carrington	Langdon	Carrington	Carrington	Carrington	Average across studies
			June 1 plant date	June 7 plant date	June 12 plant date	
year	2022	2022	2023	2023	2023	
	Yield (pounds/acre)					
Unbagged heads	**3212** b*	NO DATA	**1689** a	**1361** a	**2265** a	**2132** a
HDPE bag[1] (used in 2020-2021)	**2578** a	NO DATA	**1514** a	**1176** a	**1442** b	**1677** b
Monofilament bag[1] (used in 2022-2023)	**2451** a	NO DATA	**1374** a	**899** a	**1367** b	**1523** b
F, *P*>*F*:	34.47, < 0.0001		2.17, 0.1618	3.69, 0.0631	33.35, 0.0006	12.99, 0.0066
CV:	5.3		12.6	25.9	10.2	9.9

IMPACT OF LEAVING HEADS UNBAGGED:

27 to 40% increase in yield

[1] **Type of pollinator-exclusion bag used. HDPE:** 16 x 18 in. (40.64 x 45.72 cm) perforated HDPE plastic bags with a 336-micron pore diameter and 24% of the surface open (Midco Global; Kirkwood, MO). **Monofilament:** 15.5 x 30 in. (39.4 x 26.2 cm) monofilament mesh bags with 2.5 mm x 1 mm holes (Midco Global; Kirkwood, MO).

All of pollinator-exclusion bags tested had similar impacts on disease and yield in the absence of introduced bees or bee-vectored biological control

Testing conducted on sunflowers inoculated with lab-generated ascospores of *S. sclerotiorum*

location of study	Carrington	Carrington	Average across studies	Carrington	Carrington	Average across studies
year	2022	June 1 plant date 2023		2022	June 1 plant date 2023	
	Sclerotinia head rot incidence (%)			**Sclerotinia head rot sev. index** (%)		
Unbagged heads	**7** b*	**84** a	**45** a	**7** b*	**82** a	**44** a
Lawson bag[1] (used in 2018-2019)	**29** a	**85** a	**57** a	**28** a	**83** a	**55** a
HDPE bag[1] (used in 2020-2021)	**26** a	**85** a	**55** a	**25** a	**80** a	**53** a
Monofilament bag[1] (used in 2022-2023)	**35** a	**85** a	**60** a	**33** a	**83** a	**58** a
F, *P*>*F*:	18.57, < 0.0001	0.1, 0.9592	1.26, 0.4265	17.77, < 0.0001	0.4, 0.7561	1.22, 0.4371
CV:	30.6	5.6	14.8	31.4	5.6	14.9
	Yield (pounds/acre)			**Sclerotia contamination** (% by weight)		
Unbagged heads	**3212** b*	**1689** a	**2450** a	**1.1** b*	**10.7** ab	**5.9** a
Lawson bag[1] (used in 2018-2019)	**2557** a	**1418** a	**1988** a	**3.0** a	**7.1** a	**5.0** a
HDPE bag[1] (used in 2020-2021)	**2578** a	**1514** a	**2046** a	**2.6** a	**12.7** b	**7.7** a
Monofilament bag[1] (used in 2022-2023)	**2451** a	**1374** a	**1912** a	**3.8** a	**12.5** b	**8.1** a
F, *P*>*F*:	34.47, < 0.0001	2.17, 0.1618	4.89, 0.1126	12.7, 0.0001	8.94, 0.0046	1.14, 0.4580
CV:	5.3	12.6	7.3	21.5	16.3	29.0

[1] **Type of pollinator-exclusion bag used. HDPE:** 16 x 18 in. (40.64 x 45.72 cm) perforated HDPE plastic bags with a 336-micron pore diameter and 24% of the surface open (Midco Global; Kirkwood, MO). **Lawson:** 16 x 18 in. (40.64 x 45.72 cm) mesh bags with 1 mm x 1 mm holes (Lawson Bags; Northfield, IL). **Monofilament:** 15.5 x 30 in. (39.4 x 26.2 cm) monofilament mesh bags with 2.5 mm x 1 mm holes (Midco Global; Kirkwood, MO).

In sunflowers not inoculated with *S. sclerotiorum,* yield gains from honeybee-facilitated outcrossing were observed.

location of study (county)	Foster	Foster	Cavalier	Wells	Foster	Cavalier	Foster	Foster	Cavalier	Average across all studies
year	2023	2022	2022	2021	2021	2021	2020	2020	2020	
number of distances evaluated	3	4	4	4	4	5	5	5	5	
type of bee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	
market class	confection	confection	confection	confection	confection	confection	confection	confection	confection	
Sclerotinia head rot incidence (%)										
exposed to bees, *inoculated with pathogen*	**41** b	**28** b	**12** b	**23** b	**4** b	**27** b	**22** b	**17** b	**9** a	**20** b
bees excluded, *inoculated with pathogen*	**63** c	**44** b	**35** c	**70** c	**8** b	**41** b	**47** c	**45** c	**16** a	**41** c
exposed to bees, no pathogen inoculation	**1** a	**1** a	**1** a	**0.1** a	**0.2** a	**4** a	**2** a	**1** a	**14** a	**3** a
bees excluded, no pathogen inoculation	**1** a	**0** a	**2** a	**0.2** a	**0.3** a	**0** a	**1** a	**2** a	**10** a	**2** a
F, *P*>*F*:	172.85, < 0.0001	28.43, < 0.0001	42.99, < 0.0001	923.10, < 0.0001	29.93, < 0.0001	108.56, < 0.0001	119.21, < 0.0001	71.93, < 0.0001	1.75, 0.1787	25.31 < 0.0001
CV:	24.6	54.4	38.3	12.9	64.0	32.7	31.8	39.3	84.3	67.1
Sclerotinia head rot severity index (%)										
exposed to bees, *inoculated with pathogen*	**39** b	**27** b	**8** b	**23** b	**4** b	**27** b	**21** b	**16** b	NO DATA	**21** b
bees excluded, *inoculated with pathogen*	**62** c	**43** b	**28** c	**69** c	**7** c	**41** b	**47** c	**44** c	NO DATA	**43** c
exposed to bees, no pathogen inoculation	**0.5** a	**0.4** a	**0.4** a	**0.1** a	**0.2** a	**3.7** a	**1.6** a	**1.2** a	NO DATA	**1** a
bees excluded, no pathogen inoculation	**0.7** a	**0.3** a	**1.2** a	**0.2** a	**0.2** a	**0.5** a	**0.5** a	**0.7** a	NO DATA	**1** a
F, *P*>*F*:	176.66, < 0.0001	39.58, < 0.0001	48.88, < 0.0001	913.93, < 0.0001	31.61, < 0.0001	107.78, < 0.0001	121.93, < 0.0001	101.08, < 0.0001		33.23, < 0.0001
CV:	24.5	48.0	40.2	13.0	62.9	32.9	31.7	37.3		60.4
Yield (lbs/ac)										
exposed to bees, *inoculated with pathogen*	**1047** b	**2320** a	NO DATA	**2872** a*	**1313** a	**1892** b	**2001** a	**1904** a	**1376** a	**1841** ab
bees excluded, *inoculated with pathogen*	**1449** ab	**1892** b	NO DATA	**2295** b	**1267** a	**1637** b	**1737** b	**1666** b	**1243** a	**1648** b
exposed to bees, no pathogen inoculation	**1723** a	**2190** ab	NO DATA	**2967** a	**1426** a	**2793** a	**2155** a	**1942** a	**1288** a	**2060** a
bees excluded, no pathogen inoculation	**1595** a	**2163** ab	NO DATA	**2869** a	**1320** a	**2458** a	**2058** a	**1967** a	**1331** a	**1970** a
F, *P*>*F*:	5.52, 0.0094	3.89, 0.0264		13.34, < 0.0001	2.94, 0.0536	24.24, < 0.0001	10.34, < 0.0001	11.32, < 0.0001	1.38, 0.2687	6.12, 0.0037
CV:	23.9	12.8		10.6	10.2	18.8	10.9	8.5	14.4	10.9
Sclerotia contamination of grain (% by weight)										
exposed to bees, *inoculated with pathogen*	**3.6** b	**2.7** b	**0.2** a	**2.3** b	**0.6** b	**0.8** a	**3.3** b	**3.1** b	NO DATA	**2.1** a
bees excluded, *inoculated with pathogen*	**4.3** b	**6.4** b	**1.2** b	**9.3** c	**0.6** b	**7.9** b	**7.4** c	**6.1** c	NO DATA	**5.4** b
exposed to bees, no pathogen inoculation	**0.1** a	**0.0** a	**0.0** a	**0.3** a	**0.2** ab	**0.7** a	**0.5** a	**0.9** a	NO DATA	**0.3** a
bees excluded, no pathogen inoculation	**0.0** a	**0.1** a	**0.0** a	**0.4** a	**0.1** a	**0.4** a	**0.6** a	**0.6** a	NO DATA	**0.3** a
F, *P*>*F*:	110.78, < 0.0001	12.93, < 0.0001	10.34, 0.0003	102.27 < 0.0001	5.64, 0.0045	24.76, < 0.0001	84.73, < 0.0001	53.10, < 0.0001		19.53, < 0.0001
CV:	26.8	95.9	131.7	34.3	107.3	86.7	33.5	35.0		75.7

In non-inoculated sunflowers (no lab-grown ascospores of *S. sclerotiorum* applied), **head rot pressure was low, and exposure to bees had no impact on disease.**

Average across all studies

	Sclerotinia head rot incidence (%)	Sclerotinia head rot sev. index (%)	Sclerotia contamination (%)
exposed to bees, *inoculated with pathogen*	**20** b	**21** b	**2.1** a
bees excluded, *inoculated with pathogen*	**41** c	**43** c	**5.4** b
exposed to bees, no pathogen inoculation	**3** a	**1** a	**0.3** a
bees excluded, no pathogen inoculation	**2** a	**1** a	**0.3** a
F, *P*>*F*:	25.31 < 0.0001	33.23, < 0.0001	19.53, < 0.0001
CV:	67.1	60.4	75.7

9 field studies, 2020-2023:
Foster County (Carrington REC),
Wells County,
Cavalier County

Impact of bees & bee-vectored biocontrol tested relative to distance from hives

location of study (county)	Foster	Foster	Cavalier	Wells	Foster	Cavalier	Foster	Foster	Cavalier
year	2023	2022	2022	2021	2021	2021	2020	2020	2020
number of distances evaluated	3	4	4	4	4	5	5	5	5
type of bee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee
market class	confection	confection	confection	confection	confection	confection	confection	confection	confection
Sclerotinia head rot incidence (%)									
exposed to bees, *inoculated with pathogen*	**41** b	**28** b	**12** b	**23** b	**4** b	**27** b	**22** b	**17** b	**9** a
bees excluded, *inoculated with pathogen*	**63** c	**44** b	**35** c	**70** c	**8** b	**41** b	**47** c	**45** c	**16** a
exposed to bees, no pathogen inoculation	**1** a	**1** a	**1** a	**0.1** a	**0.2** a	**4** a	**2** a	**1** a	**14** a
bees excluded, no pathogen inoculation	**1** a	**0** a	**2** a	**0.2** a	**0.3** a	**0** a	**1** a	**2** a	**10** a
F, *P*>*F*:	172.85, < 0.0001	28.43, < 0.0001	42.99, < 0.0001	923.10, < 0.0001	29.93, < 0.0001	108.56, < 0.0001	119.21, < 0.0001	71.93, < 0.0001	1.75, 0.1787
CV:	24.6	54.4	38.3	12.9	64.0	32.7	31.8	39.3	84.3
Sclerotinia head rot severity index (%)									
exposed to bees, *inoculated with pathogen*	**39** b	**27** b	**8** b	**23** b	**4** b	**27** b	**21** b	**16** b	NO DATA
bees excluded, *inoculated with pathogen*	**62** c	**43** b	**28** c	**69** c	**7** c	**41** b	**47** c	**44** c	NO DATA
exposed to bees, no pathogen inoculation	**0.5** a	**0.4** a	**0.4** a	**0.1** a	**0.2** a	**3.7** a	**1.6** a	**1.2** a	NO DATA
bees excluded, no pathogen inoculation	**0.7** a	**0.3** a	**1.2** a	**0.2** a	**0.2** a	**0.5** a	**0.5** a	**0.7** a	NO DATA
F, *P*>*F*:	176.66, < 0.0001	39.58, < 0.0001	48.88, < 0.0001	913.93, < 0.0001	31.61, < 0.0001	107.78, < 0.0001	121.93, < 0.0001	101.08, < 0.0001	
CV:	24.5	48.0	40.2	13.0	62.9	32.9	31.7	37.3	
Sclerotia contamination of grain (% by weight)									
exposed to bees, *inoculated with pathogen*	**3.6** b	**2.7** b	**0.2** a	**2.3** b	**0.6** b	**0.8** a	**3.3** b	**3.1** b	NO DATA
bees excluded, *inoculated with pathogen*	**4.3** b	**6.4** b	**1.2** b	**9.3** c	**0.6** b	**7.9** b	**7.4** c	**6.1** c	NO DATA
exposed to bees, no pathogen inoculation	**0.1** a	**0.0** a	**0.0** a	**0.3** a	**0.2** ab	**0.7** a	**0.5** a	**0.9** a	NO DATA
bees excluded, no pathogen inoculation	**0.0** a	**0.1** a	**0.0** a	**0.4** a	**0.1** a	**0.4** a	**0.6** a	**0.6** a	NO DATA
F, *P*>*F*:	110.78, < 0.0001	12.93, < 0.0001	10.34, 0.0003	102.27 < 0.0001	5.64, 0.0045	24.76, < 0.0001	84.73, < 0.0001	53.10, < 0.0001	
CV:	26.8	95.9	131.7	34.3	107.3	86.7	33.5	35.0	

In non-inoculated sunflowers (no lab-grown ascospores of *S. sclerotiorum* applied), **head rot pressure was low, and exposure to bees was generally associated with an increase in yield**

- average 4.6% increase
- not statistically significant but consistent with expected result (increased outcrossing)

9 field studies, 2020-2023:
Foster County (Carrington REC), Wells County, Cavalier County

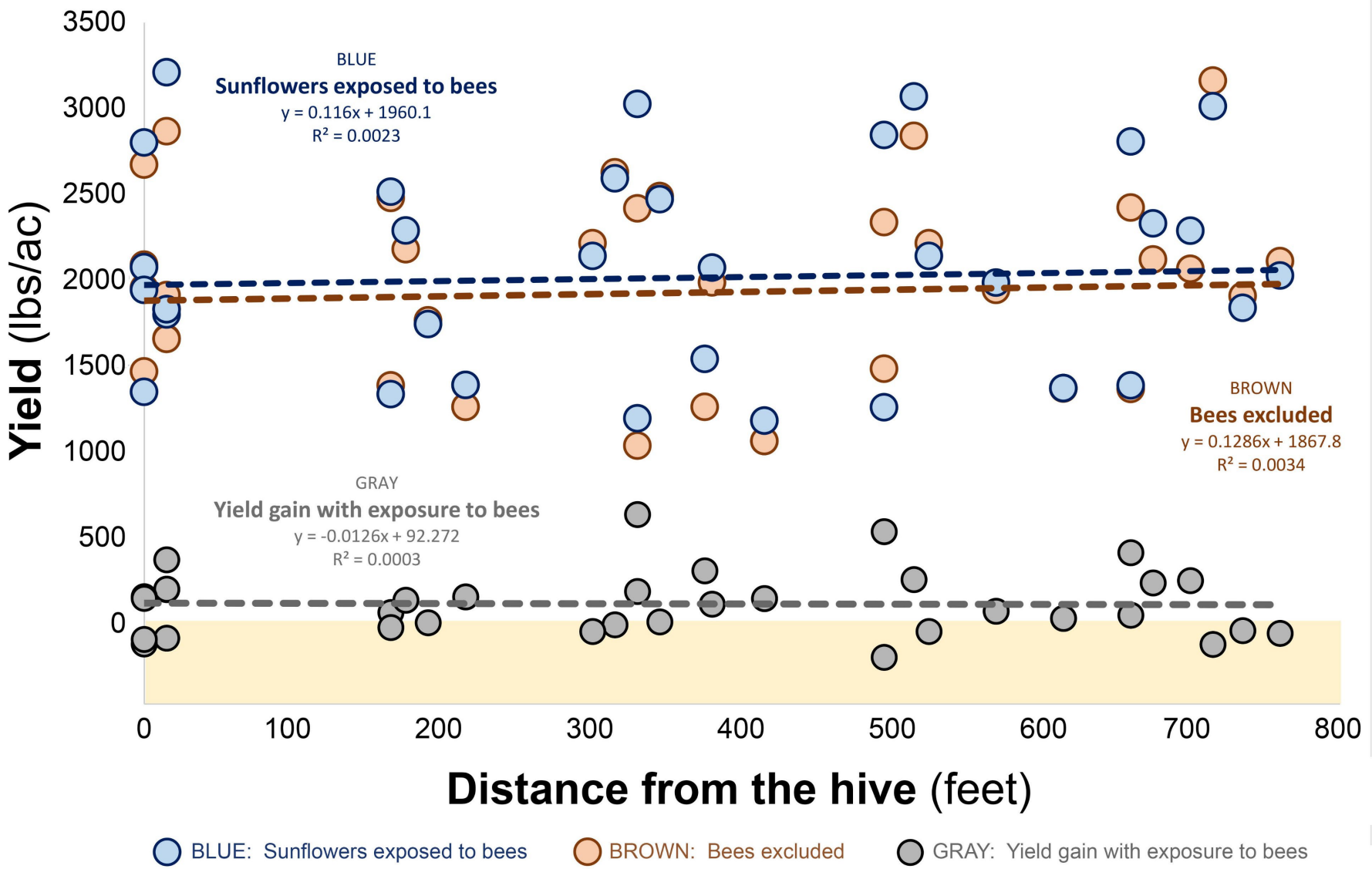
Impact of bees & bee-vectored biocontrol tested relative to distance from hives

	Average across all studies
	Yield (lbs/ac)
exposed to bees, *inoculated with pathogen*	**1841** ab
bees excluded, *inoculated with pathogen*	**1648** b
exposed to bees, no pathogen inoculation	**2060** a
bees excluded, no pathogen inoculation	**1970** a
F, *P*>*F*:	6.12, 0.0037
CV:	10.9

location of study (county)	Foster	Foster	Cavalier	Wells	Foster	Cavalier	Foster	Foster	Cavalier
year	2023	2022	2022	2021	2021	2021	2020	2020	2020
number of distances evaluated	3	4	4	4	4	5	5	5	5
type of bee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee
market class	confection	confection	confection	confection	confection	confection	confection	confection	confection
	Yield (lbs/ac)								
exposed to bees, *inoculated with pathogen*	**1047** b	**2320** a	NO DATA	**2872** a*	**1313** a	**1892** b	**2001** a	**1904** a	**1376** a
bees excluded, *inoculated with pathogen*	**1449** ab	**1892** b	NO DATA	**2295** b	**1267** a	**1637** b	**1737** b	**1666** b	**1243** a
exposed to bees, no pathogen inoculation	**1723** a	**2190** ab	NO DATA	**2967** a	**1426** a	**2793** a	**2155** a	**1942** a	**1288** a
bees excluded, no pathogen inoculation	**1595** a	**2163** ab	NO DATA	**2869** a	**1320** a	**2458** a	**2058** a	**1967** a	**1331** a
F, *P*>*F*:	5.52, 0.0094	3.89, 0.0264		13.34, < 0.0001	2.94, 0.0536	24.24, < 0.0001	10.34, < 0.0001	11.32, < 0.0001	1.38, 0.2687
CV:	23.9	12.8		10.6	10.2	18.8	10.9	8.5	14.4

In non-inoculated sunflowers (no lab-grown ascospores of *S. sclerotiorum* applied), **head rot pressure was low, and exposure to bees was generally associated with an increase in yield**

- Response was consistent across distances from hive tested.



Conclusions

Due to the confounding influence of the pollinator-exclusion bags, efficacy of bee-vectored biological control is not clear

- The increased reduction in disease observed in the studies with introduced bees, bee-vectored biological control suggests bee-vectored *C. rosea* may have some degree of efficacy.
- Large-field studies in which long transects are established from bee hives would be needed to rigorously evaluate efficacy

Testing conducted on non-inoculated sunflowers suggests that the introduction of honeybees may facilitate modest yield increases

- Average yield increase of 4.6% observed across all distances assessed
- Not statistically significant but consistent with the expected result from increased outcrossing

Thank you!

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