

NDSU Carrington Research Extension Center **Michael Wunsch**, Suanne Kallis, Jesse Hafner, Aaron Fauss, Xavier Klocke and Thomas Miorini

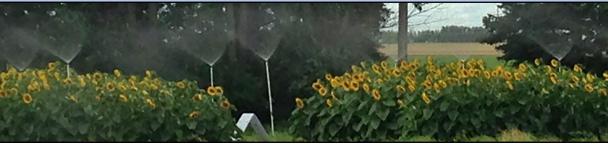
NDSU Langdon Research Extension Center Venkata Chapara and Amanda Arens



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)





LangdonLangdon20162017NuSun '306'NuSun '306'

Sclerotinia head rot incidence (% of plants)

no bees 39

exposed to bees 26



e (% of pla 35

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).

Sunflower yield (pounds/acre)

bagged heads 1880

unbagged heads 2053



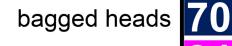
Preliminary testing (2017, 2019) – Non-oil sunflowers, honeybee-vectored *Clonostachys rosea*

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)*



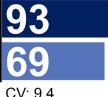






unbagged heads





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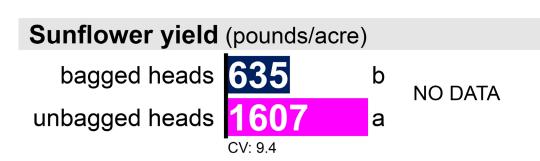
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INOCULATIONS:

- 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 noninoculated 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 vectored

Average across all studies

Sclerotinia head rot incidence (%)

exposed to bees and bees vectored biological control:exposed to bees, inoculated with pathogen24 a 4 b46% 6ductionbes excluded, inoculated with pathogen44 bbes excluded, inoculated with pathogen44 bF, P>F:46.52, < 0.0001 22.2bes excluded, inoculated with pathogen6001costion of study (county) Foster year 2023Foster 2022costion of			·						•	,				
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	exposed to b	Dees	and	hee-		expo	sed to bee	s, inoculat	ed with pa	thogen	2	24 a	469	%
Iocation of study (county) Foster year 2023 Foster Cavalier Foster Cavalier Foster	•					bees	s excluded	l, inoculate	ed with pati	hogen	4	14 b		
Iocation of study (county) Foster year 2023 Foster Cavalier Cavalier Cavalier Cavalier Cavalier Foster Cavalier Foster Cavalier Foster Cavalier		logic			•					F, P>1	F: 46.5	52, < 0.000)1	
year202320222022202120212021202120212020202020202017201620172016number of distances evaluated 344455511<										C	V:	22.2		
number of distances evaluated 3 4 4 4 4 5 5 5 1 1 1 1 1 type of bee honeybee market class confection honeybee confection honeybee honeybee honeybee honeybee confection honeybee confection honeybee honeybee<	location of study (county)	Foster	Foster	Cavalier	Wells	Foster	Cavalier	Foster	Foster	Cavalier	Foster	Foster	Cavalier	Cavalier
type of bee market class confectionhoneybee confection <t< td=""><td>year</td><td>2023</td><td>2022</td><td>2022</td><td>2021</td><td>2021</td><td>2021</td><td>2020</td><td>2020</td><td>2020</td><td>2019</td><td>2018</td><td>2017</td><td>2016</td></t<>	year	2023	2022	2022	2021	2021	2021	2020	2020	2020	2019	2018	2017	2016
market class confection confection<	number of distances evaluated	3	4	4	4	4	5	5	5	5	1	1	1	1
Sclerotinia backbook 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 a 26 b 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 b 39 a exposed to bees, no pathogen inoculation 1 a 1 a 0.1 a 0.2 a 4 a 2 a 1 a 14 a NO DATA NO are prepriored	type of bee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	bumblebee	bumblebee
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 0.1 a 0.2 a 4 a 2 a 1 a 14 a NO DATA NO D	market class	confection	confection	confection	confection	confection	confection	confection	confection	confection	confection	confection	oilseed	oilseed
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 0.1 a 0.2 a 4 a 2 a 1 a 14 a NO DATA		Sclerotinia	head rot incid	lence (%)										
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 NO DATA	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, no pathogen inoculation 1 a 0 a 2 0.2 a 0.3 a 0 a 1 a 2 a 10 a NO DATA	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
F, P>F: 172.85, < 0.0001	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
CV: 24.6 54.4 12.9 64.0 32.7 31.8 39.3 84.3 9.4 16.0 study study	F, P>F:	172.85, < 0.00	001 28.43, < 0.000)1	923.10, < 0.0001	29.93, < 0.0001	1 108.56, < 0.000	1 119.21, < 0.0001	71.93, < 0.0001	1.75, 0.1787	15.04, 0.0605	43.05, 0.0028	non-replicated	non-replicated
	CV:	24.6	54.4		12.9	64.0	32.7	31.8	39.3	84.3	9.4	16.0	study	study

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 year	2022	Langdon 2022	Carrington June 1 plant date 2023	Carrington June 7 plant date 2023	Carrington June 12 plant date 2023		IMPACT OF LEAVING HEADS UNBAGGED:
	Sclerotinia hea	d rot incidence ('	%)				
Unbagged heads	7 b*	5 a*	84 a	63 a	41 a	40 a	22 to 26%
HDPE bag ¹ (used in 2020-2021)	26 a	9 a	85 a	72 ab	65 b	51 ab	reduction in disease
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	

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 bacs with 2.5 mm x 1 mm holes (Midco Global; Kirkwood, MO).

Reduction in disease observed in Sclerotinia-inoculated sunflowers exposed vectored

Average across

all studies

Sclerotinia head rot severity index (%)

					\sim $-$								
exposed to	exposed to bees and bee-							lated with p		20 a	50%	6	
vectored bi					be	es exclud	ed, inocula	ated with pa	thogen		41 b		uction
	ologic								F, P>	F: 29	.68, 0.0003	3	
									С	V:	28.9		
location of study (cour	ty) Foster	Foster	Cavalier	Wells	Foster	Cavalier	Foster	Foster	Cavalier	Foster	Foster	Cavalier	Cavalier
ye	ear 2023	2022	2022	2021	2021	2021	2020	2020	2020	2019	2018	2017	2016
number of distances evaluat	ed 3	4	4	4	4	5	5	5	5	1	1	1	1
type of b	ee honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	bumblebee	bumblebee
market cla	iss confection	confection	confection	confection	confection	confection	confection	confection	confection	confection	confection	oilseed	oilseed
	Sclerotinia I	head rot seve	rity 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, < 0.000	1 39.58, < 0.000)1	913.93, < 0.000	01 31.61, < 0.0	001 107.78, < 0.00	001 121.93, < 0.00	001 101.08, < 0.000)1		44.19, 0.0027	non-replicated	non-replicated
c	CV: 24.5	48.0		13.0	62.9	32.9	31.7	37.3			15.9	study	study

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 year	Carrington	Langdon 2022	Carrington June 1 plant date 2023	Carrington June 7 plant date 2023	Carrington June 12 plant date 2023		IMPACT OF LEAVING HEADS UNBAGGED:
	Sclerotinia head	d rot severity ind	ex (%)				04 - 0004
Unbagged heads	7 b*	4 a*	82 a	62 b	41 a	39 a	21 to 26%
HDPE bag¹ (used in 2020-2021)	25 a	6 a	80 a	71 ab	64 b	49 ab	reduction in disease
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	

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 beevectored biological control:

Foster

2022

honeybee

confection

2.7 b

6.4 b

0.0 a

0.1 a

95.9

Sclerotia contamination of grain (% by weight)

4

Cavalier

honeybee

confection

0.2

1.2

0.0

0.0

2022

4

Wells

2021

honeybee

confection

2.3 b

9.3 C

0.3 a

0.4 a

102.27 < 0.0001

34.3

4

location of study (county) Foster

number of distances evaluated 3

exposed to bees, inoculated with pathogen

bees excluded, inoculated with pathogen

exposed to bees, no pathogen inoculation

bees excluded, no pathogen inoculation

year 2023

type of bee honeybee

market class confection

CV:

3.6 b*±

4.3 b

0.1 a

0.0 a

26.8

F, P>F: 110.78, < 0.0001 12.93, < 0.0001

in						•	e across a udies	II	
rs			Scl	erotia c	ontamir	nation o	f grain (%)	
	expo	sed to bee	s, inoculate	ed with path	ogen		2.1 a	61	%
	bees	s excluded	, inoculated	d with patho	ogen		5.4 b		uction
					F, P>F:	1	9.53, < 0.00		
					CV:		75.7		
Foste	er	Cavalier	Foster	Foster	Cavalier	Foster	Foster	Cavalier	Cavalier
2021 4		2021 5	2020 5	2020 5	2020 5	2019 1	2018 1	2017 1	2016 1
4 hone	/bee	5 honeybee	5 honeybee	boneybee	5 honeybee	honeybee	honeybee	bumblebee	ı bumblebee
confe		confection	confection	confection	confection	confection	confection	oilseed	oilseed
0	. 6 b	0.8 a	3.3 b	3.1 b*‡	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
0	. 6 b	7.9 b	7.4 c	6.1 c	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
0	. 2 ab	0.7 a	0.5 a	0.9 a	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA

NO DATA

NO DATA

NO DATA

NO DATA

NO DATA

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

0.1 a

5.64, 0.0045

107.3

0.4 a

24.76, < 0.0001

86.7

0.6 a

33.5

0.6 a

35.0

84.73, < 0.0001 53.10, < 0.0001

location of study	Carrington	Langdon	Carrington June 1 plant date	Carrington June 7 plant date	Carrington June 12 plant date	Average across studies	IMPACT OF LEAVING
year	2022	2022	2023	2023	2023		HEADS UNBAGGED:
	Sclerotia contar	nination (% by w	eight)				
Unbagged heads	1.1 b*	NO DATA	10.7 ab	8.9 a	3.8 a	6.1 a	18 to 24%
HDPE bag ¹ (used in 2020-2021)	2.6 a	NO DATA	12.7 b	10.9 a	3.6 a	7.4 a	reduction in disease
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	

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 sunflow exposed to bees and beevectored biological control:

Foster

2022

honeybee

confection

2320 a

1892 b

2190 ab

2163 ab

3.89, 0.0264

12.8

4

Cavalier

honeybee

confection

10.6

2022

4

location of study (county) Foster

number of distances evaluated 3

exposed to bees, inoculated with pathogen

bees excluded, inoculated with pathogen

exposed to bees, no pathogen inoculation

bees excluded, no pathogen inoculation

year 2023

type of bee honeybee

market class confection

F. P>F:

CV.

Yield (lbs/ac) 1047 b

1449 ab

1723 a

1595 a

5.52, 0.0094

23.9

in Iower:	S						all	age across studies d (Ibs/ac		
	е	exposed to be	ees, inocula	ated with p	athogen		183	31 a	14%	
	b	bees exclude	e <mark>d,</mark> inocula	ted with pa	thogen		160)7 a		ease
					F, P> C	>F: CV:	4.	05, 0.0718 15.2	_	
Wells	Foster	Cavalier	Foster	Foster	Cavalier	Foste	er	Foster	Cavalier	Cavalier
2021	2021	2021	2020	2020	2020	2019)	2018	2017	2016
4	4	5	5	5	5	1		1	1	1
honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	hone	ybee	honeybee	bumblebee	bumblebee
confection	confection	confection	confection	confection	confection	confe	ection	confection	oilseed	oilseed
2872 a*	1313 a	1892 b	2001 a	1904 a*	1376 a*	N	O DATA	1607 a*	1761	2053
2295 b	1267 a	1637 b	1737 b	1666 b	1243 a	N	O DATA	635 b	1981	1880
2967 a	1426 a	2793 a	2155 a	1942 a	1288 a	N	O DATA	NO DATA	NO DATA	NO DATA
2869 a	1320 a	2458 a	2058 a	1967 a	1331 a	N	O DATA	NO DATA	NO DATA	NO DATA
13.34, < 0.0001	2.94, 0.0536	õ 24.24, < 0.0001	10.34, < 0.0001	11.32, < 0.0001	1.38, 0.2687			102.44, 0.0005	non-replicated	non-replicated

14 4

study

study

63

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

10.2

18.8

10.9

85

location of study	Carrington	Langdon 2022	Carrington June 1 plant date 2023	Carrington June 7 plant date 2023	Carrington June 12 plant date 2023	Average across studies	IMPACT OF LEAVING HEADS UNBAGGED:
	Yield (pounds/ac	cre)					
Unbagged heads	3212 b*	NO DATA	1689 a	1361 a	2265 a	2132 a	27 to 40%
HDPE bag¹ (used in 2020-2021)	2578 a	NO DATA	1514 a	1176 a	1442 b	1677 b	increase in yield
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	

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 year	Carrington 2022	Carrington June 1 plant date 2023	Average across studies	Carrington 2022	Carrington June 1 plant date 2023	Average across studies
	Sclerotinia head r	ot incidence (%)		Sclerotinia head r	ot 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	e)		Sclerotia contami	nation (% by weigh	t)
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) year	Foster 2023	Foster 2022	Cavalier 2022	Wells 2021	Foster 2021	Cavalier 2021	Foster 2020	Foster 2020	Cavalier 2020	•
number of distances evaluated	3	4	4	4	4	5	5	5	5	Average across all studies
type of bee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	
market class	confection	confection	confection	confection	confection	confection	confection	confection	confection	
	Sclerotinia h	ead rot incid	lence (%)							
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 h	lead rot seve	rity index (%	o)						
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
	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
	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 co	ntamination	o f grain (% b	y 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.

on disease.				Average across all studies								
					otinia he cidence			inia hea index (%		Sclei contamin		
	expo	sed to bees, inoculated with	pathogen		20 b		2 [.]	1 b		2.1	а	
	bee	s excluded, inoculated with	pathogen		41 c		43 c			5.4	b	
	exp	osed to bees, no pathogen i	noculatior	n la	3 a		•	1 a		0.3	а	
	be	es excluded, no pathogen i	noculatior	n <mark>a ana ana ana ana ana ana ana ana ana </mark>	2 a		•	1 a		0.3	а	
			F, P>F	25.31 < 0.000			33.23, -			19.53, <	0.0001	
			CV	:	67.1			60.4		75		
			Faster	Frates	0	14/- II-	Faster	0	Frates	Frates	Ormalian	
9 field studies, 2020-2023:		location of study (county)	Foster 2023	Foster 2022	Cavalier 2022	Wells 2021	Foster 2021	Cavalier 2021	Foster 2020	Foster 2020	Cavalier 2020	
Foster County (Carrington R	REC),	number of distances evaluated		4	4	4	4	5	5	5	5	
Wells County,		type of bee		honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee	
Cavalier County		market class	confection	confection	confection	confection	confection	confection	confection	confection	confection	
			Sclerotinia	head rot incid	dence (%)							
Impact of bees & bee-vector	ed	exposed to bees, inoculated with pathogen	41 b	28 b	12 b	23 b	4 b	27 b	22 b	17 b	9 a	
biocontrol tested relative to		bees excluded, inoculated with pathogen	63 c	44 b	35 c	70 c	8 b	41 b	47 c	45 c	16 a	
distance from hives		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	
				28.43, < 0.0001	42.99, < 0.0001					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	3 39.3	84.3	
			Sclerotinia	head rot seve	erity 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		NO DATA	
			176.66, < 0.0001	39.58, < 0.0001 48.0		913.93, < 0.0001				0.0001 101.08, < 0.000	1	
		CV: 24.5			40.2	13.0	62.9	32.9	31.7	37.3		
		exposed to bees, inoculated with pathogen 3.6 b					0.0 h	0.9 0	226	24 h	NO DATA	
		, , , , , , , , , , , , , , , , , , , ,		2.7 b	0.2 a	2.3 b	0.6 b	0.8 a	3.3 b		NO DATA	
	bees excluded, inoculated with pathogen 4.3 exposed to bees, no pathogen inoculation 0.1		4.3 D 0.1 a	6.4 b	1.2 b 0.0 a	9.3 c 0.3 a	0.6 b	7.9 b 0.7 a	7.4 c 0.5 a		NO DATA	
				0.0 a	0.0 a	0.3 a	0.2 ab	0.7 a 0.4 a	0.5 a		NO DATA	
	bees excluded, no pathogen inoculation 0.0 a				10.34, 0.0003	0.4 a 102.27 < 0.0001	0.1 a	0.4 a 24.76, < 0.0001	0.6 a			
		CV:	26.8	95.9	10.34, 0.0003 131.7	102.27 < 0.0001 34.3	5.64, 0.0045 107.3	24.76, < 0.0001 86.7	84.73, < 0 33.5		1	

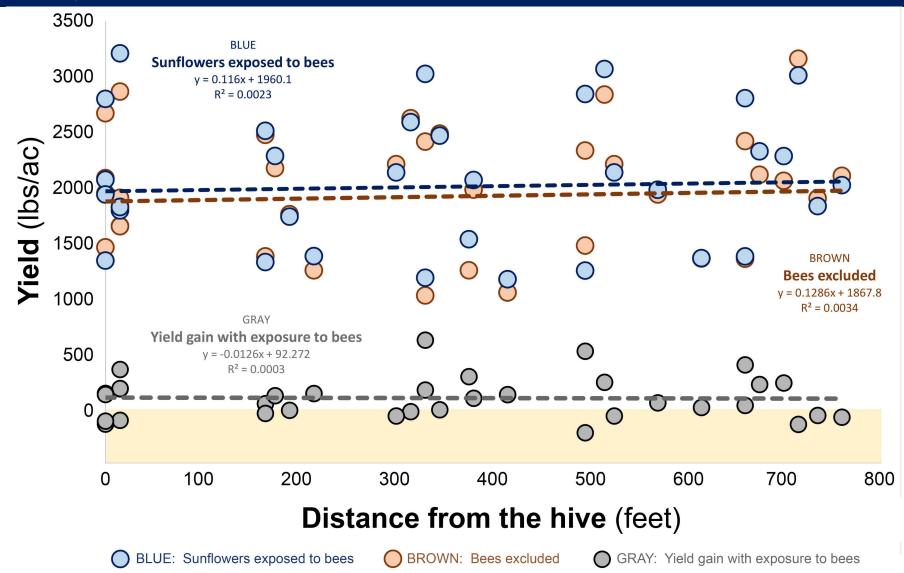
In non-inoculated sunflowers (no lab-grown ascospores of *S. sclerotiorum* applied), head rot pressure was low, and exposure to bees was generally associated with an increase in yield

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

9 field studies, 2020-2023: Foster County (Carrington REC), N	Wells County	/,							Average ac all studie	
Cavalier County									Yield (lb	s/ac)
Impact of bees & bee-vectored bic distance from hives	control teste	ed relative to		exp	osed to bee	es, inocula	ted with pa	thogen	1841 a	b
				be	es exclude	d, inocula	ted with pa	thogen	1648 b)
				ex	posed to be	ees, <mark>no pa</mark>	thogen ino	culation	2060 a	
				b	ees excluc	led, no pa	thogen ino	culation	1970 a	1
			1					F, P>F:	6.12, 0.00)37
								CV:	10.9	
location of study (county)	Foster 2023	Foster 2022	Cavali 2022	er	Wells 2021	Foster 2021	Cavalier 2021	Foster 2020	Foster 2020	Cavalier 2020
number of distances evaluated		4	4		4	4	5	5	5	5
type of bee		honeybee	honeyb	ee	honeybee	honeybee	honeybee	honeybee	honeybee	honeybee
market class		confection	confecti		confection	confection	confection	confection	confection	confection
	Yield (lbs/ad	c)								
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
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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, < 0.000	1 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!

FUNDING:

Preliminary testing, 2016-2019: BVT, Inc. *Field trials, 2020-2023:* USDA Specialty Crop Block Grant Program

NDSU Carrington Research Extension Center Michael Wunsch, Suanne Kallis, Jesse Hafner, Aaron Fauss, Xavier Klocke and Thomas Miorini

NDSU Langdon Research Extension Center Venkata Chapara and Amanda Arens

