Fig. 1. Brown scarring, leaf puckering and distorted growing point caused by swede midge feeding in collards. Photo: C. Hoepting.

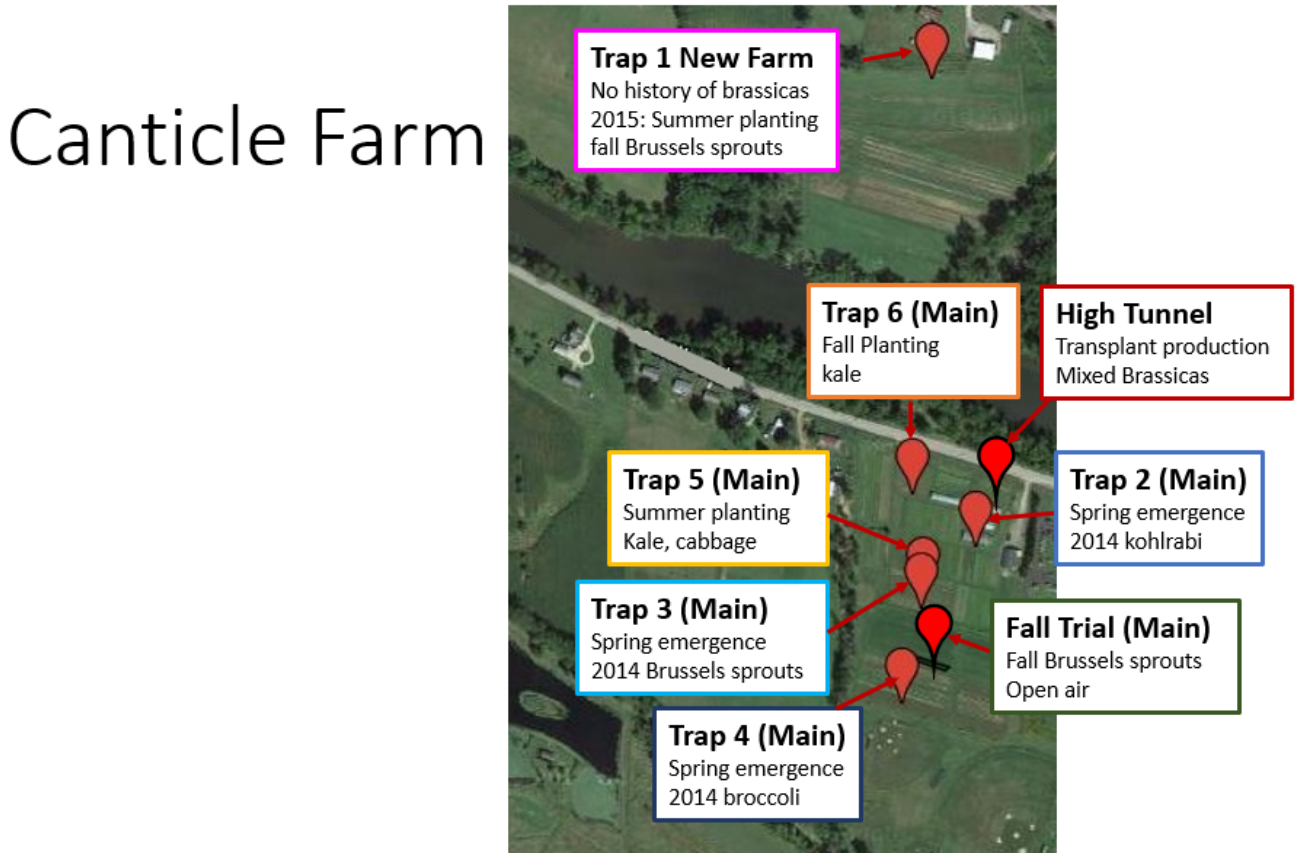
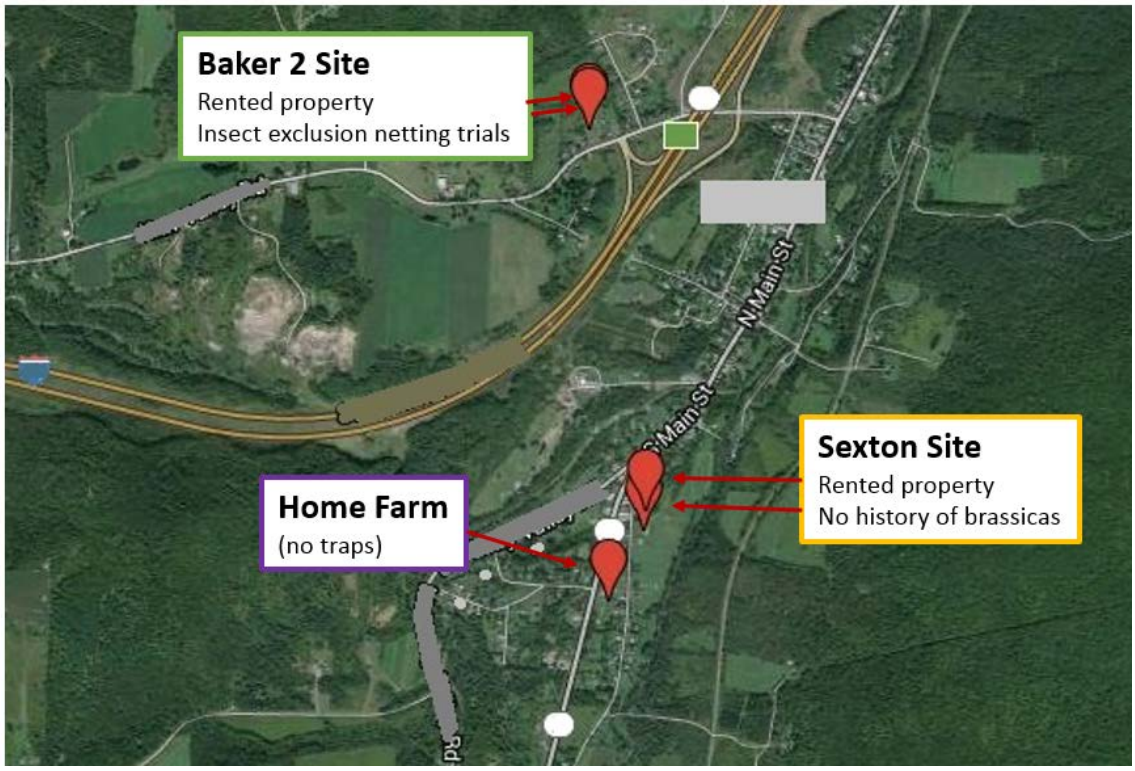
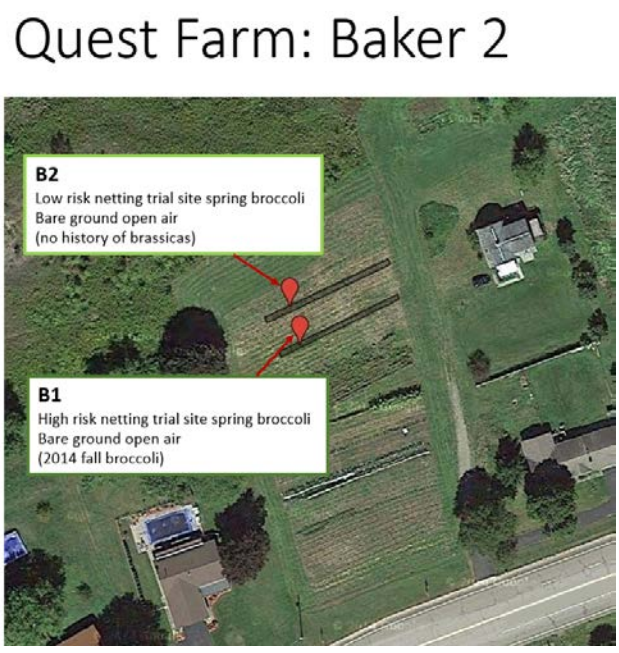


Fig. 2. Farm and swede midge trap layout for Canticle Farm, Allegany, NY (Cattaraugus Co.), 2015.

a)



b)



c)

Fig. 3. Farm (a) and trap layout (b,c) for Quest Produce Farm, Almond, NY (Allegany Co.), 2015.

Living Acres Farm

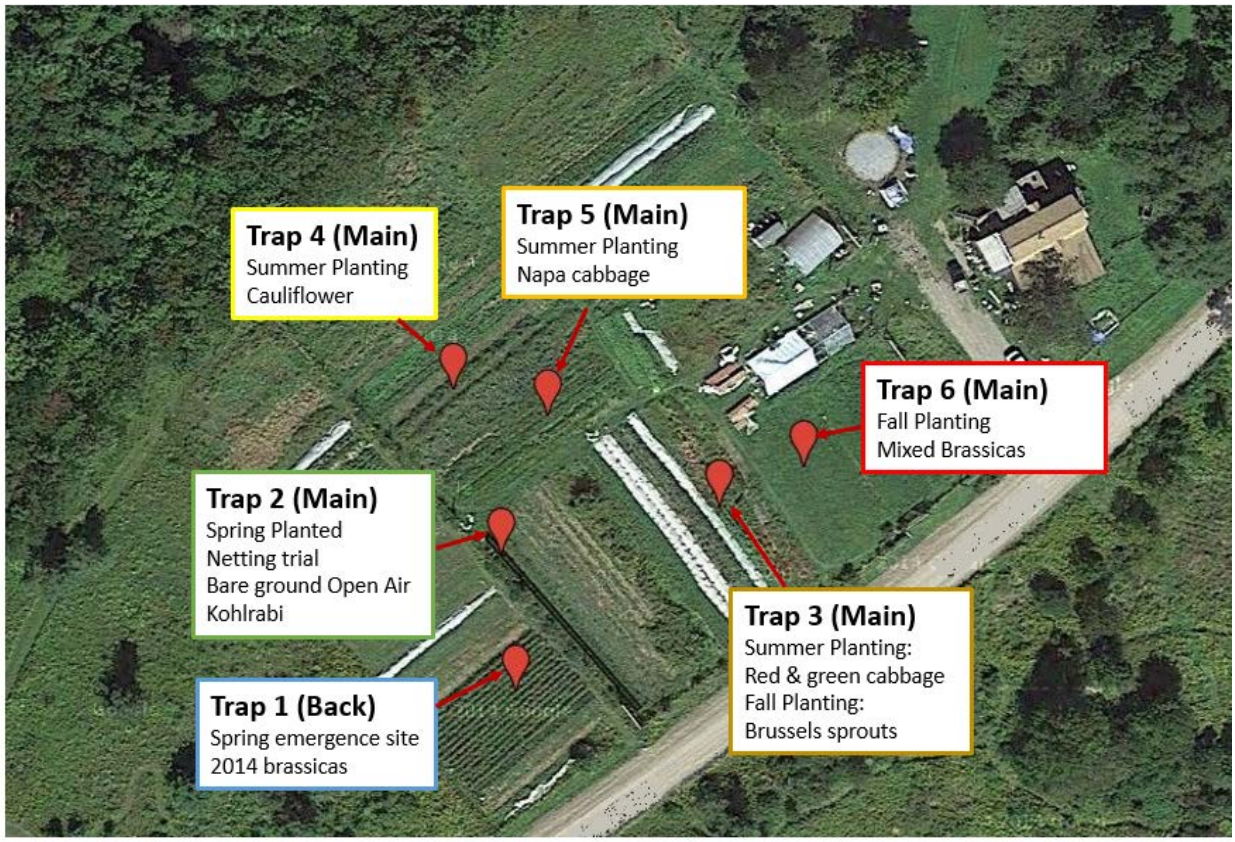


Fig. 4. Farm and swede midge trap layout for Living Acres, Alfred Station, NY (Allegany Co.), 2015. This was a rented property; the home farm was about 2 miles away, but had no brassica production except for brassica transplants that were produced inside a greenhouse.

Fellenz Family Farm

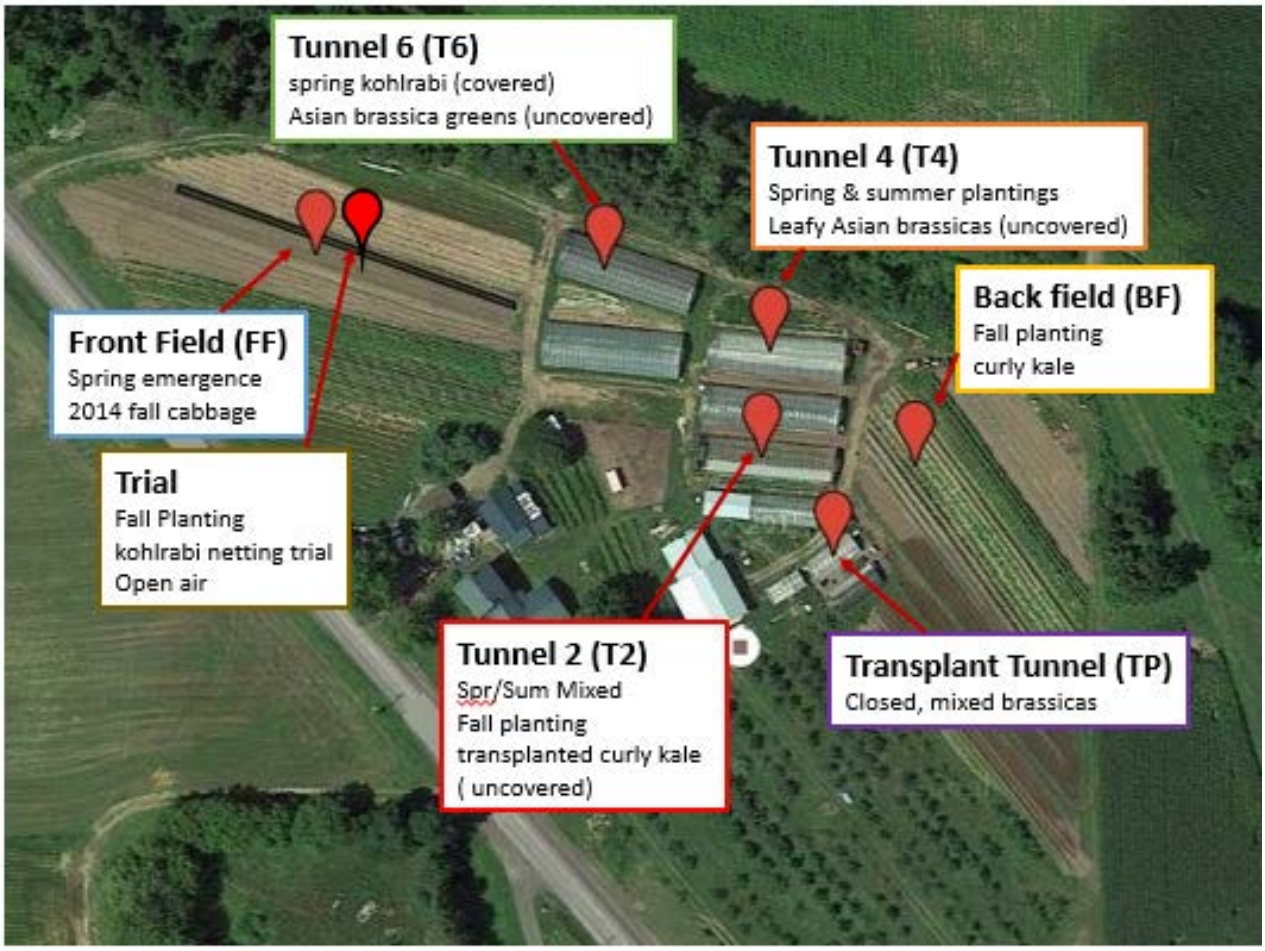


Fig. 5. Farm and swede midge trap layout for Fellenz Family Farm, Phelps, NY (Ontario Co.), 2015.

Muddy Fingers

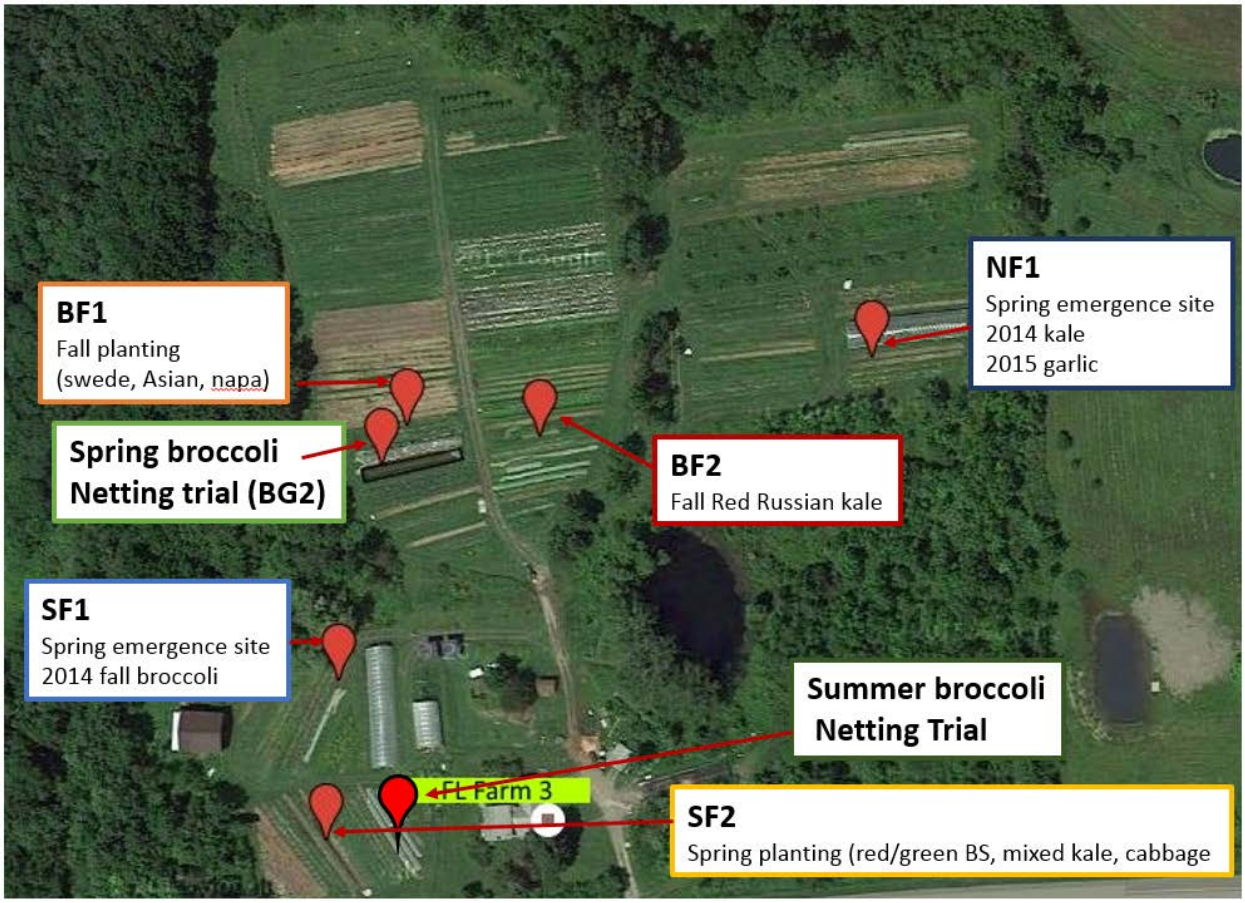
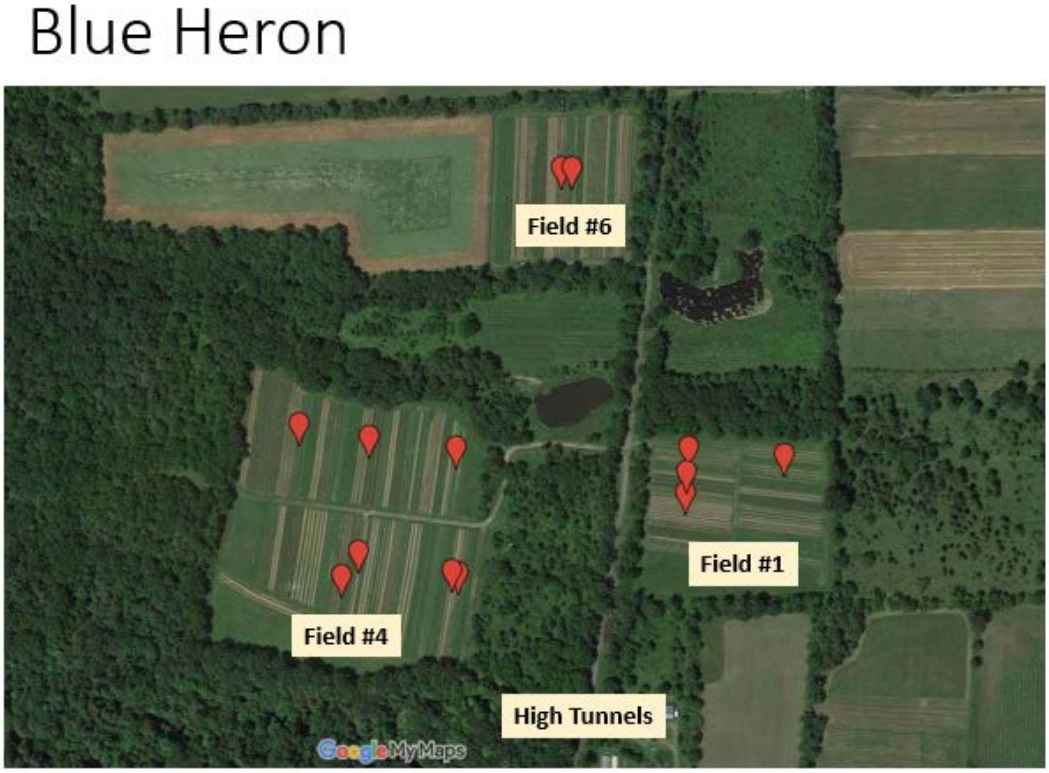


Fig. 6. Farm and swede midge trap layout for **Muddy Fingers**, Hector, NY (Schuyler Co.), 2015.

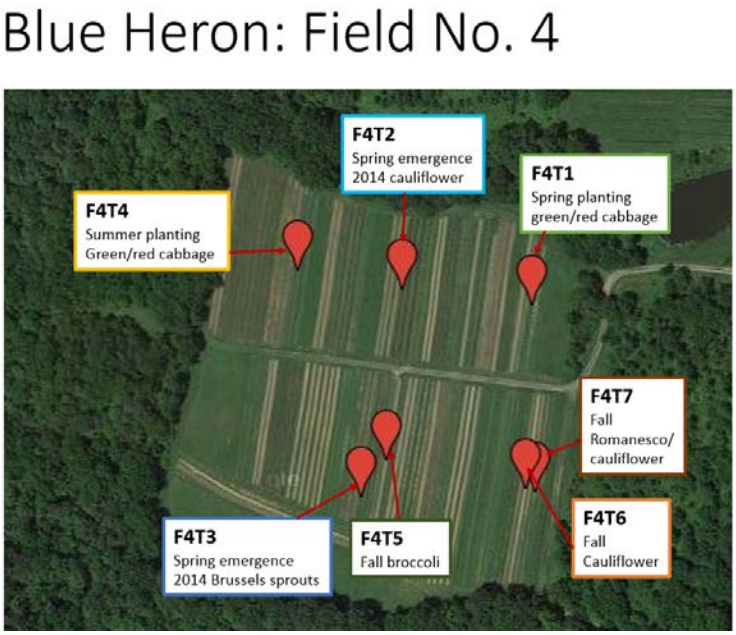
a)



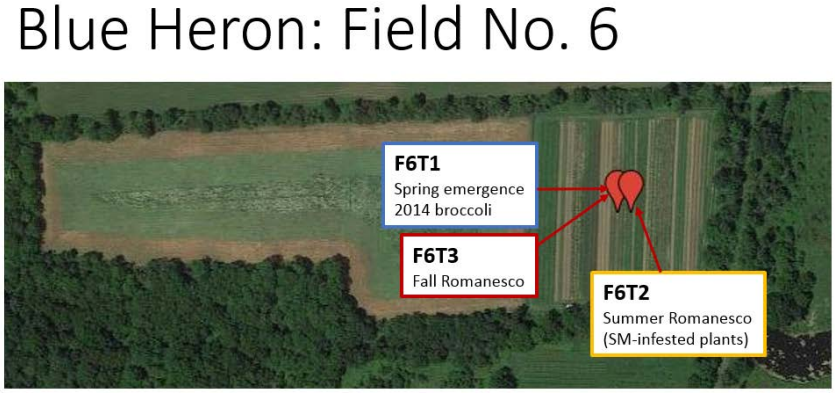
b)

Fig. 7. Farm (a) and swede midge trap layout in field 1 (b) for Blue Heron, Lodi, NY (Seneca Co.), 2015.

a)



b)



c)

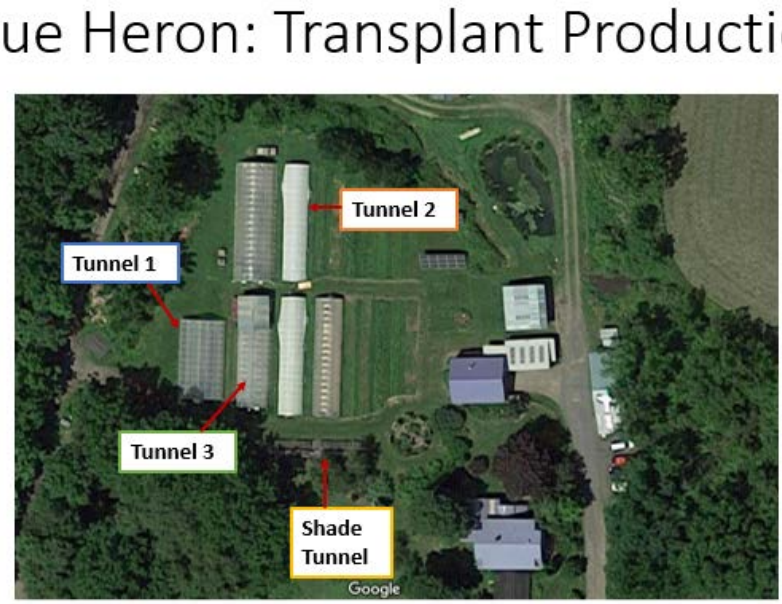


Fig. 8. Swede midge trap layout in field 4 (a), 6 (b) and transplant production (c) for Blue Heron, Lodi, NY (Seneca Co.), 2015.

Table 1. Optimizing management of new invasive species, swede midge on small-scale organic farms, 2015: Background information on participating case study farms and on-farm trials.

Grower Cooperator Farm Name	Location (County)	Total Acres	Acres of Cole Crops	Source of Cole Crop Transplants	Standard Planting Practices	SM history	General SM pressure	On-Farm Trials
Mark Printz **Canticle Farm**	3835 South Nine Mile Rd, Allegany, NY 14706 **(Cattaraugus)**	8	1 **(12.5%)**	Grow own in greenhouse	**Bare ground & bio-tello plastic,** 5' wide bed 2 rows/bed	80% crop loss in spring broccoli (does not grow anymore), minor damage in fall Brussels sprouts, broccoli, red cabbage, kohlrabi	**Minor-Moderate** (10% crop loss, especially in Brussels sprouts, broccoli in fall)	• **Insect exclusion netting in fall Brussels sprouts** (bare ground, bio-tello mulch)
Dennis & Bridget Reynolds **Quest Farm Produce**	7142 State Rte 21, Almond, NY **(Allegany)**	4	0.12 **(=3%)**	Grow own in greenhouse	**Bare ground** 4' wide bed 2 rows/bed	Learned about SM in 2014: minor damage in spring broccoli and kohlrabi. Moderate-severe damage in fall broccoli.	**Minor-Moderate** (10-70% crop loss, especially broccoli)	• **Insect exclusion netting in spring broccoli** (high risk vs. low risk site; bare ground, straw mulch, black plastic mulch) • Garlic oil repellent trial
Sasha & Amanda Khodorkovskiy **Living Acres**	2052 Hemlock Hill Road, Alfred Station **(Allegany)**	3	0.25 **(=8.3%)**	Grow own in greenhouse	**Black plastic & bare ground** 4'wide bed	Loss in broccoli, kohlrabi and certain varieties of kale during 2013 & 2014.	**Moderate** (25-50% crop loss in some plantings)	• **Insect exclusion netting in spring kohlrabi** (bare ground, black plastic mulch) • Garlic oil repellent trial
Liz Martin & Matthew Glen **Muddy Fingers**	3859 Dugue Rd, Hector, NY **(Schuyler)**	3	0.5-0.75 **(=17-25%)**	Grow own in greenhouse	**Bare ground** 42" wide bed 2 rows/bed	100% crop loss of broccoli in 2011, 2012 & 2014. Success with exclusion netting in 2013; failure in 2014.	**Moderate-Severe** (100% loss in some plantings, especially broccoli)	• **Insect exclusion netting in spring broccoli** (bare ground, black plastic mulch, landscape fabric, hay mulch) • **Insect exclusion netting in late-summer broccoli** (black plastic mulch, landscape fabric, hay mulch)
Robin Ostfeld & Lou Johns **Blue Heron**	1641 Shaw Rd, Lodi, NY **(Seneca)**	12	1.5-2.0 **(=12.5-17%)**	Grow own in greenhouse	**Bare ground,** 6' wide bed 4 rows/bed	First noticed in 2013. 100% crop loss of fall cauliflower, 75% loss of broccoli. Observable differences among varieties (20-100%).	**Minor-Severe** (broccoli & some varieties of cauliflower, 0 to 100% loss)	
Andy Fellenz **Fellenz Family Farm**	1919 Lester Road, Phelps. NY 14456 **(Ontario)**	5	0.5 **(=10%)**	Grow own in greenhouse	**Bare ground**, 4-5' wide beds 2-3 rows/bed	Problematic in fall kohlrabi, In fall 2012, lost 100% broccoli & 50% kohlrabi, reduced losses now due to extended rotations and reduced plantings, does not grow broccoli anymore.	**Minor** (<10% crop loss, especially in fall kohrabi, more severe outbreaks in the past)	• **Insect exclusion netting in fall kohlrabi** (bare ground, black plastic mulch, straw mulch)

a)  b) 

c) 

Fig. 9. Trap for monitoring swede midge. a) Trap set up about 1 foot off of the ground within the crop canopy. b) Trap set up in a spring emergence site (cropped to SM-infested brassica crop during previous fall. c) Close-up of Jackson trap with pheromone lure (changed every 4 weeks) and sticky liner (changed every week. Photos: C. Hoepting.

Table 2. Monitoring swede midge population dynamics using pheromone traps on small-scale organic farms in New York, 2015: **Trap inventory for Canticle**, Allegany, NY (Cattaraugus Co.).

Trap Code	Farm Name	Trap Location	Trap Type	Planting Date	Date Set-up	Date Taken Down	No. weeks trap deployed	Crops
1	Canticle	New farm	No brassicas in over 10 years Summer planting	Early-June	May 29	Sep 17	16	2015 fall Brussels sprouts
1	Canticle	Main farm High Tunnel	Transplant production, partially open		May 1	May 29	4	Mixed Brassica transplants
2	Canticle	Main farm Beside Barn	spring emergence site		May 1	Nov 12	28	2014 fall kohlrabi 2015 Swiss chard
3	Canticle	Main farm Middle Field	spring emergence site		May 1	Sep 9	18.9	2014 Fall Brussels sprouts 2015 Green beans
4	Canticle	Main farm Back Field	Spring emergence site		May 1	Jul 7	9.7	2014 Fall broccoli 2015 Rye cover crop
5	Canticle	Main farm Middle Field	summer planting	Mid-June	Jun 7	Oct 28	20.4	mixed kale, cabbage
6	Canticle	Main farm Front Field	Fall planting	Mid-August	Sep 3	Oct 28	7.9	Mixed kale
Fall Trial	Canticle	Main farm Back field	Fall Brussels sprouts netting trial	Jun 19	Jun 19	Nov 12	20.7	Brussels sprouts

Spring planting – April and May
Summer plating – June and early July
Fall planting – late July and later

Table 3. Monitoring swede midge population dynamics using pheromone traps on small-scale organic farms in New York, 2015: **Trap inventory for Quest Farm Produce**, Almond, NY (Allegany Co.).

Trap Code	Farm Name	Trap Location	Trap Type	Planting Date	Date Set-up	Date Taken Down	No. weeks trap deployed	Crops
B1	Quest	Baker 2	Spring Emergence Netting Trial **Low risk site** (no history of brassicas) Bare ground Open Air	Early May	May 15	Oct 28	11.7	spring broccoli netting trial (not harvested)
B2	Quest	Baker 2	Spring Emergence Netting Trial **High risk site** (broccoli 2014) Bare ground Open Air	Early May	May 15	Oct 28	11.7	2014 fall broccoli spring broccoli netting trial (not harvested)
S1	Quest	Sexton 1	Summer Planting No history or brassicas	Early June	Jun 4	Nov 12	23.0	Spring broccoli Summer cabbage
S2	Quest	Sexton 2	Fall planting History of brassicas	Early September	Sep 17	Nov 12	8.1	Mixed kale

Spring planting – April and May
Summer plating – June and early July
Fall planting – late July and later

Table 4. Monitoring swede midge population dynamics using pheromone traps on small-scale organic farms in New York, 2015: **Trap inventory for Living Acres**, Alfred Station, NY (Allegany Co.).

Trap Code	Farm Name	Trap Location	Trap Type	Planting Date	Date Set-up	Date Taken Down	No. weeks trap deployed	Crops
1	Living Acres	Back field	Spring Emergence Site		May 1	Nov 12	28	2014 SM-infested Brassicas 2015 onions
2	Living Acres	Main field	Netting Trial Spring Planting kohlrabi Bare ground Open Air	Early May	May 15	Nov 12	25.9	Kohlrabi
3	Living Acres	Main field	Summer Planting	Early June	Jun 19	Sep 25	14	Green & red cabbage Winterbor & dino kale
4	Living Acres	Main field	Summer Planting	Late June	Jun 24	Nov 12	20.3	Cauliflower, Brussels sprouts
5	Living Acres	Main field	Summer Planting	Late June	Jun 24	Nov 12	20.3	Napa cabbage, Winterbor & dino kale
6	Living Acres	Main field	Fall Planting	Early Sep	Sep 25	Nov 12	6.9	Mixed Brassicas

Spring planting – April and May
Summer plating – June and early July
Fall planting – late July and later

Table 5. Monitoring swede midge population dynamics using pheromone traps on small-scale organic farms in New York, 2015: **Trap inventory for Fellenz Family Farm**, Phelps, NY (Ontario Co.).

Trap Code	Farm Name	Trap Location	Trap Type	Planting Date	Date Set-up	Date Taken Down	No. weeks trap deployed	Crops
FF	Fellenz	Front Field	Spring emergence site		May 6	Aug 26	16	2014 Fall Cabbage
BF	Fellenz	Back Field	Fall planting	mid-August	Aug 17	Oct 27	10.3	Curly kale
Trial	Fellenz	Front Field	Fall trial open air	mid-August	Aug 26	Oct 27	9	Kohlrabi
TP	Fellenz	Transplant production	Transplant production, closed		May 6	Jul 9	9.1	Mixed Brassica transplants
T6	Fellenz	High Tunnel #6	Spring and summer plantings	mid-April through mid-September	May 6	Nov 13	27.4	Spring kohlrabi (covered*) Asian brassicas (uncovered)
T4	Fellenz	High Tunnel #4	Spring and Summer plantings	mid-May through mid-September	Jun 25	Sep 10	11.1	Leafy Asian brassicas (uncovered)
T2	Fellenz	High Tunnel #2	Spring and summer plantings Fall planting	Mid-May thru mid-September	May 27	Oct 14	22	Mixed Brassicas Transplanted curly kale, (uncovered)

*covered with row cover.

Spring planting – April and May
Summer plating – June and early July
Fall planting – late July and later

Table 6. Monitoring swede midge population dynamics using pheromone traps on small-scale organic farms in New York, 2015: **Trap inventory for Muddy Fingers Farm**, Hector, NY (Schuyler Co.).

Trap Code	Farm Name	Trap Location	Trap Type	Planting Date	Date Set-up	Date Taken Down	No. weeks trap deployed	Crops
SF1	Muddy Fingers	Small Field	Spring emergence site		Apr 30	Nov 13	28.3	2014 Fall Broccoli 2015 Parsnips
SF2	Muddy Fingers	Small Field	Spring planting	mid-May	May 27	Nov 13	24.4	Mixed brassicas Red/green BS, mixed kale, cabbage
Summer netting trial	Muddy Fingers	Small Field	Summer trial open air	Jul 1	Jul 1	Oct 27	16.9	Broccoli
NF1	Muddy Fingers	New Field	Spring emergence site		Apr 30	Sep 1	17.6	2014 kale 2015 garlic
Trial BG2	Muddy Fingers	Big Field	Spring trial bare ground	late April	May 6	Nov 13	27.4	Broccoli
BF1	Muddy Fingers	Big Field	Fall planting	mid- August	Sep 1	Nov 13	10.6	Mixed brassicas Napa, swede, Asian mustards
BF2	Muddy Fingers	Big Field	Fall planting	mid-August	Sep 1	Nov 13	10.6	Red Russian kale

Spring planting – April and May
Summer plating – June and early July
Fall planting – late July and later

Table 7. Monitoring swede midge population dynamics using pheromone traps on small-scale organic farms in New York, 2015: **Trap inventory for Blue Heron**, Lodi, NY (Seneca Co.).

Trap Code	Trap Location	Trap Type	Planting Date	Date Set-up	Date Taken Down	No. weeks trap deployed	Crops
F1T1	Field 1	Spring Emergence site		Apr 30	Aug 11	14.7	2014 Cauliflower
F1T2	Field 1	Spring Emergence site Fall Planting	Jul-31	Apr 30	Nov 13	28.1	2014 Fall Collards Red cabbage
F1T3	Field 1	Spring Emergence site Fall planting	Jul-22	Apr 30	Nov 13	28.1	2014 Fall kale Red cabbage
F1T4	Field 1	Fall planting	Jul-20	Jul 31	Oct 27	12.6	Red cabbage
F4T2	Field 4	Spring Emergence site		Apr 30	Nov 13	28.1	2014 Fall Cauliflower
F4T3	Field 4	Spring Emergence site		Apr 30	Nov 13	28.1	2014 Fall Brussels sprouts
F4T1	Field 4	Spring planting	Mid-April	Apr 30	Nov 13	28.1	Green & red cabbage
F4T4	Field 4	Summer planting	Jun-1	Jun 5	Nov 13	23	Red & green cabbage
F4T5	Field 4	Fall planting	Jul-20	Jul 31	Nov 13	15	Broccoli
F4T6	Field 4	Fall planting	Late-July	Jul 31	Nov 13	15	Cauliflower
F4T7	Field 4	Fall planting	Late-July	Jul 31	Oct 27	12.6	Cauliflower
F6T1	Field 6	spring emergence site	Jul-22	May 27	Jul 22	21.9	2014 fall broccoli
F6T2	Field 6	Summer planting	Jun-25	Jun 25	Nov 13	20.1	Romanesco (infested transplants)
F6T3	Field 6	Fall planting	Jul 22	Jul 22	Oct 27		Romanesco
ST	Shade Tunnel	Transplant production Open air with shade cloth		May 27	Oct 27	21.9	Mixed transplants
HT1	High Tunnel 1	Transplant production sides down, mostly closed		Apr 30	Jun 17	6.9	Mixed transplants
HT2	High Tunnel 2	Transplant production Sides down, mostly closed		Apr 30	May 27	3.9	Mixed transplants
HT3	High Tunnel 3	Transplant production Sides down, mostly closed		Apr 30	May 27	3.9	Mixed transplants

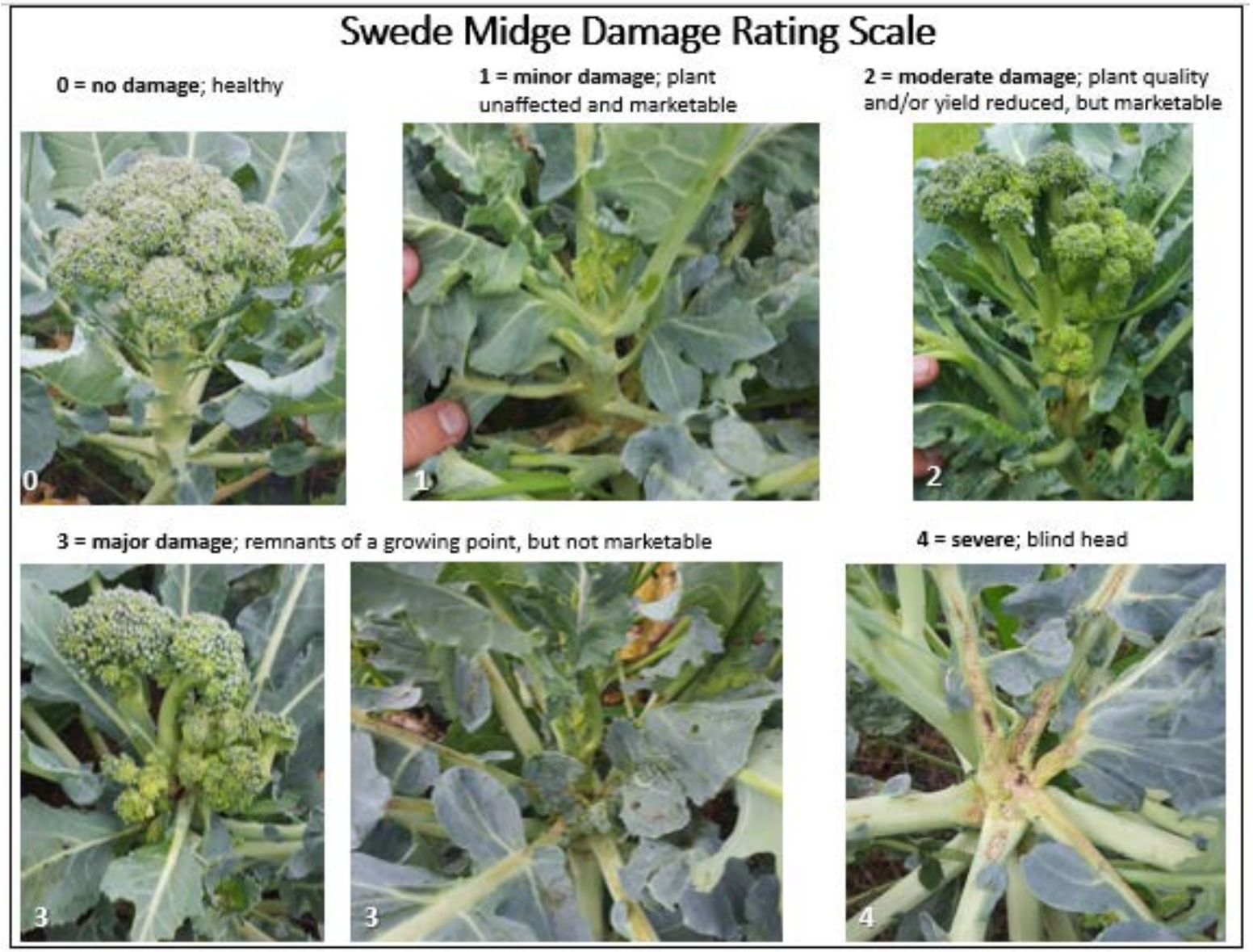


Fig. 10. Swede midge damage rating scale for crop at harvest. Developed by C.A. Hoepting. Photos: C.A. Hoepting.

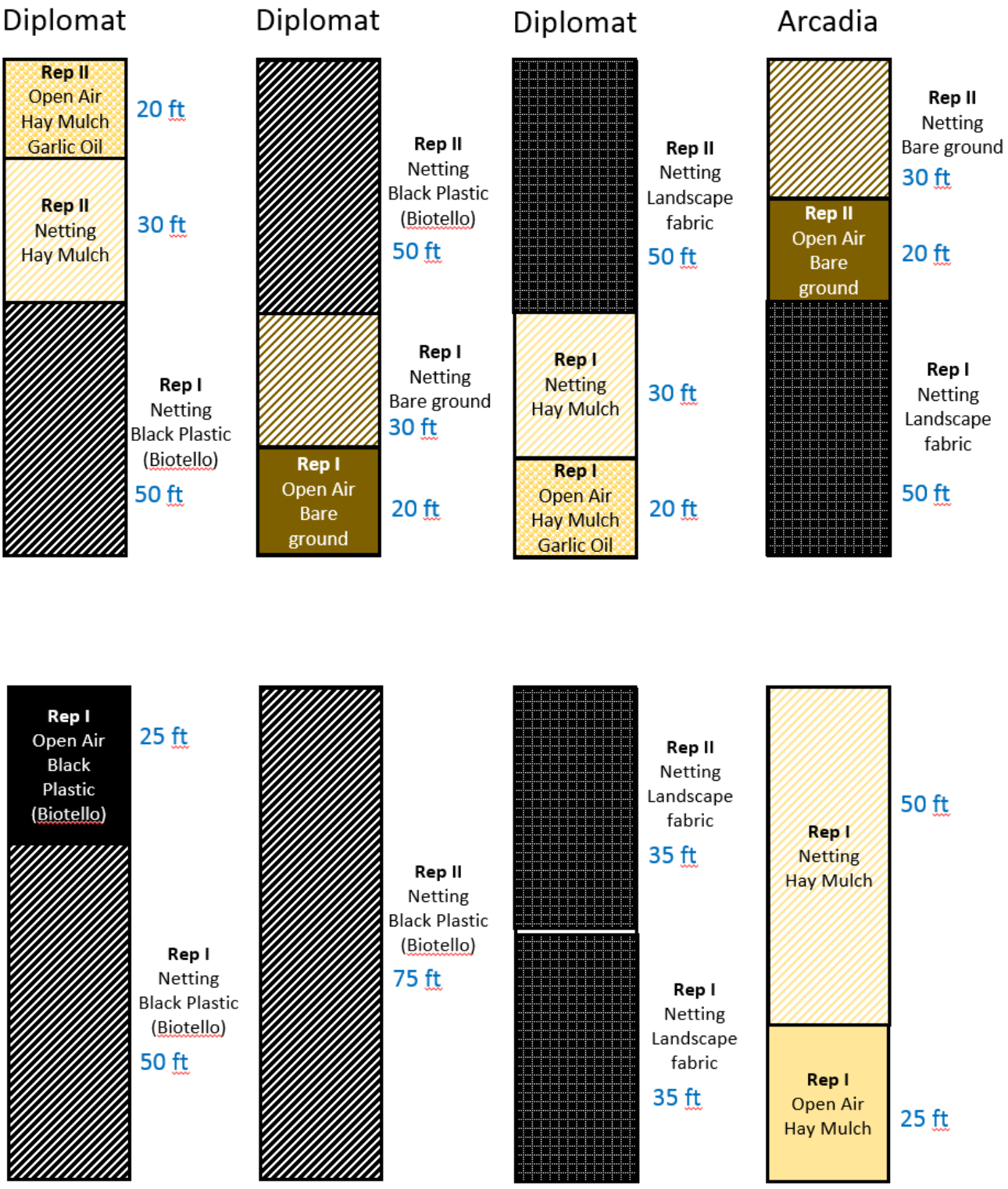


Fig. 12. Layout of insect exclusion netting trial in spring broccoli (top) and late-summer broccoli (bottom) at Muddy Fingers Farm, 2015. Growers wanted to minimize amount of broccoli in open air, so plot sizes were adjusted to accommodate their requests.

Fig. 11. ***Left:*** Insect exclusion netting (ProtekNet, 25 gram, 14 ft width, Dubois Agrinovation) set up over width of bed planted to *Brassicas*. 10-ft metal electrical conduit (Lowe's) bent with a hoop bender (Johnny's) is used to make the hoops to hold up the exclusion netting (1 hoop every 4-6 feet). Fiberglass rod posts (Zareba 48 inch, Tractor Supply Co., cut in half) are used to anchor the hoops, and snap clamps (for ½ inch EMT, Johnny's Selected Seeds) are used to hold netting onto hoops (need 2 per hoop). Netting is secured at ground with rocks or clods of sod. ***Right:*** A knotted sleeve made out of exclusion netting allows researchers to easily access swede midge trap without allowing swede midge to enter or escape the netting. Photos: C. Hoepting.

a)

b)

Fig. 13. Blind Brussels sprout caused by swede midge with characteristic brown corky scarring (a) and blind Brussels sprout not caused by swede midge (lacking brown corky scarring) (b). Photos: C. Hoepting.

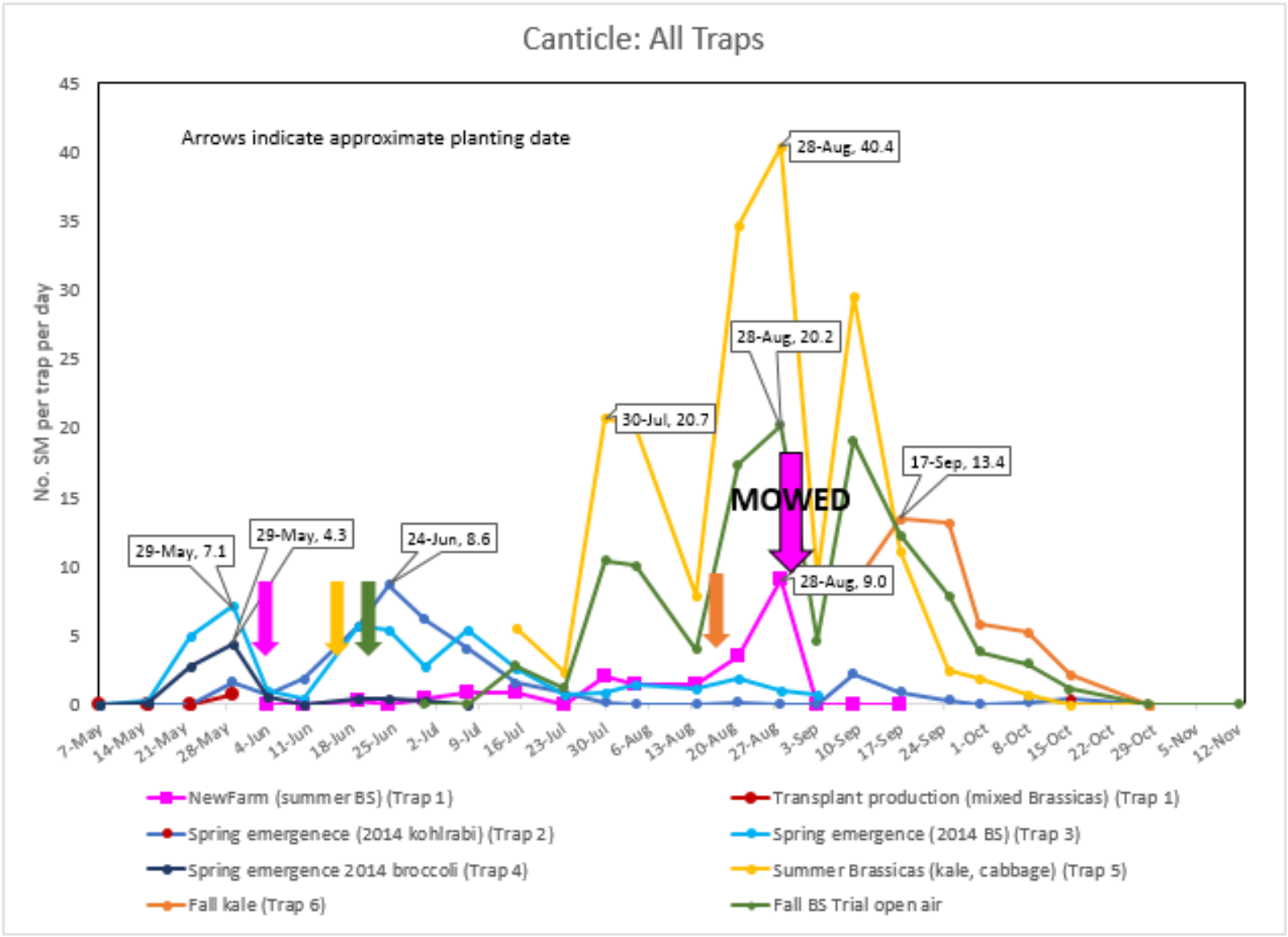


Fig. 14. Swede midge population dynamics monitored by pheromone traps at Canticle Farm, Allegany, NY, 2015.

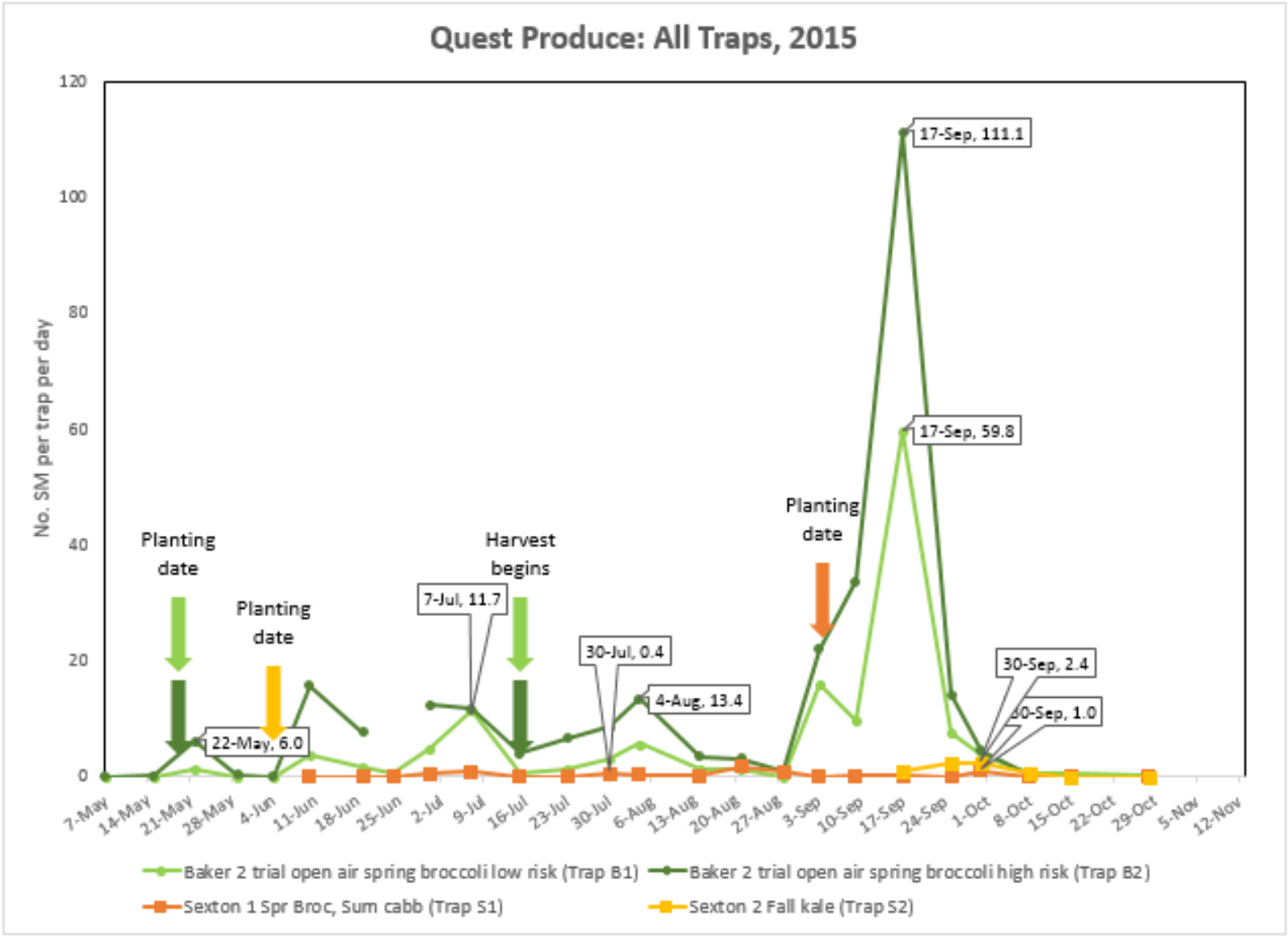


Fig. x. Swede midge population dynamics monitored by pheromone traps at Quest Produce, Almond, NY, 2015.

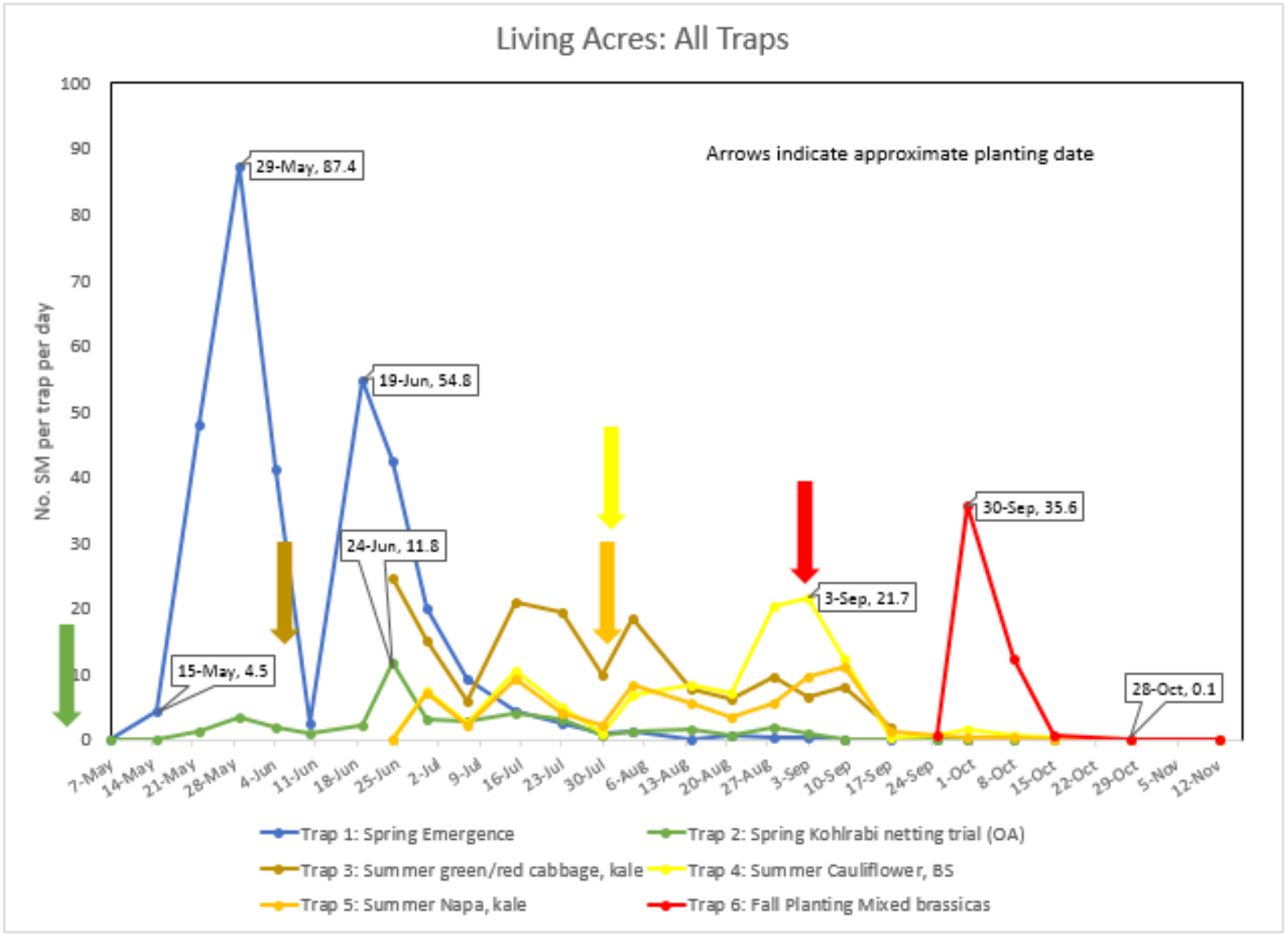


Fig. 16. Swede midge population dynamics monitored by pheromone traps at Living Acres, Alfred Station, NY, 2015.

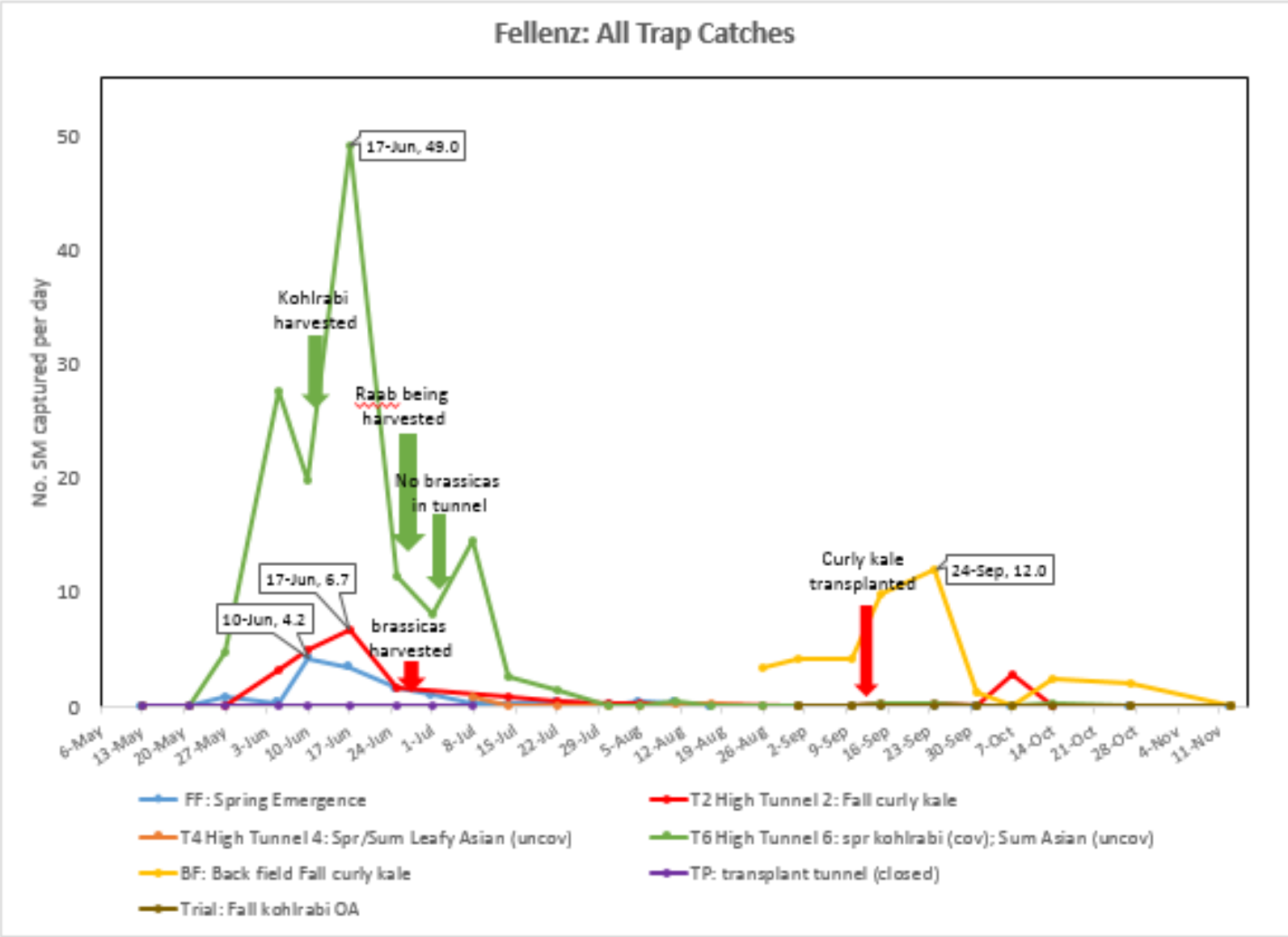


Fig. 17. Swede midge population dynamics monitored by pheromone traps at Fellenz Family Farm, Phelps, NY, 2015.

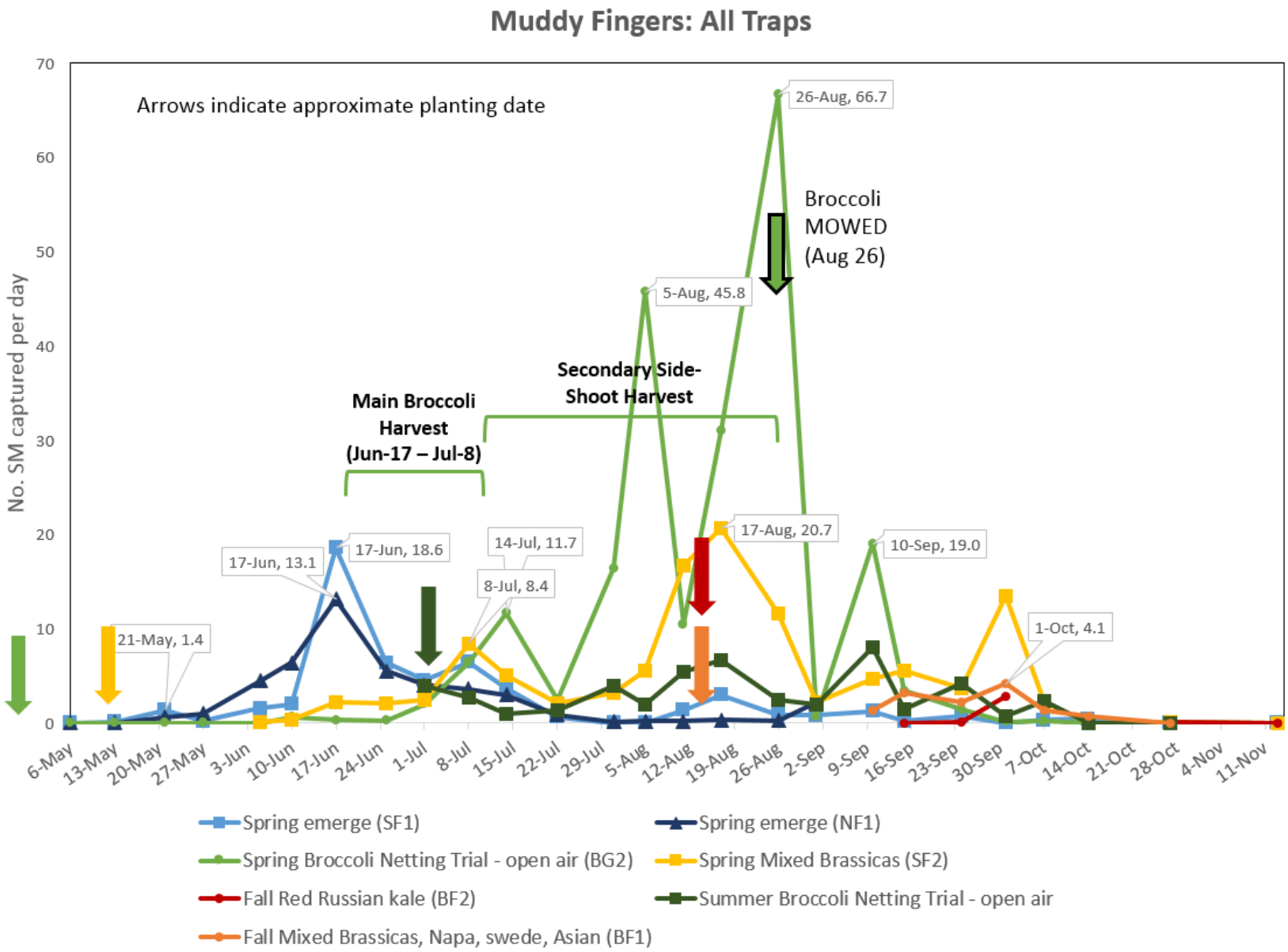


Fig. 18. Swede midge population dynamics monitored by pheromone traps at **Muddy Fingers**, Hector, NY (Schuyler Co.), 2015.

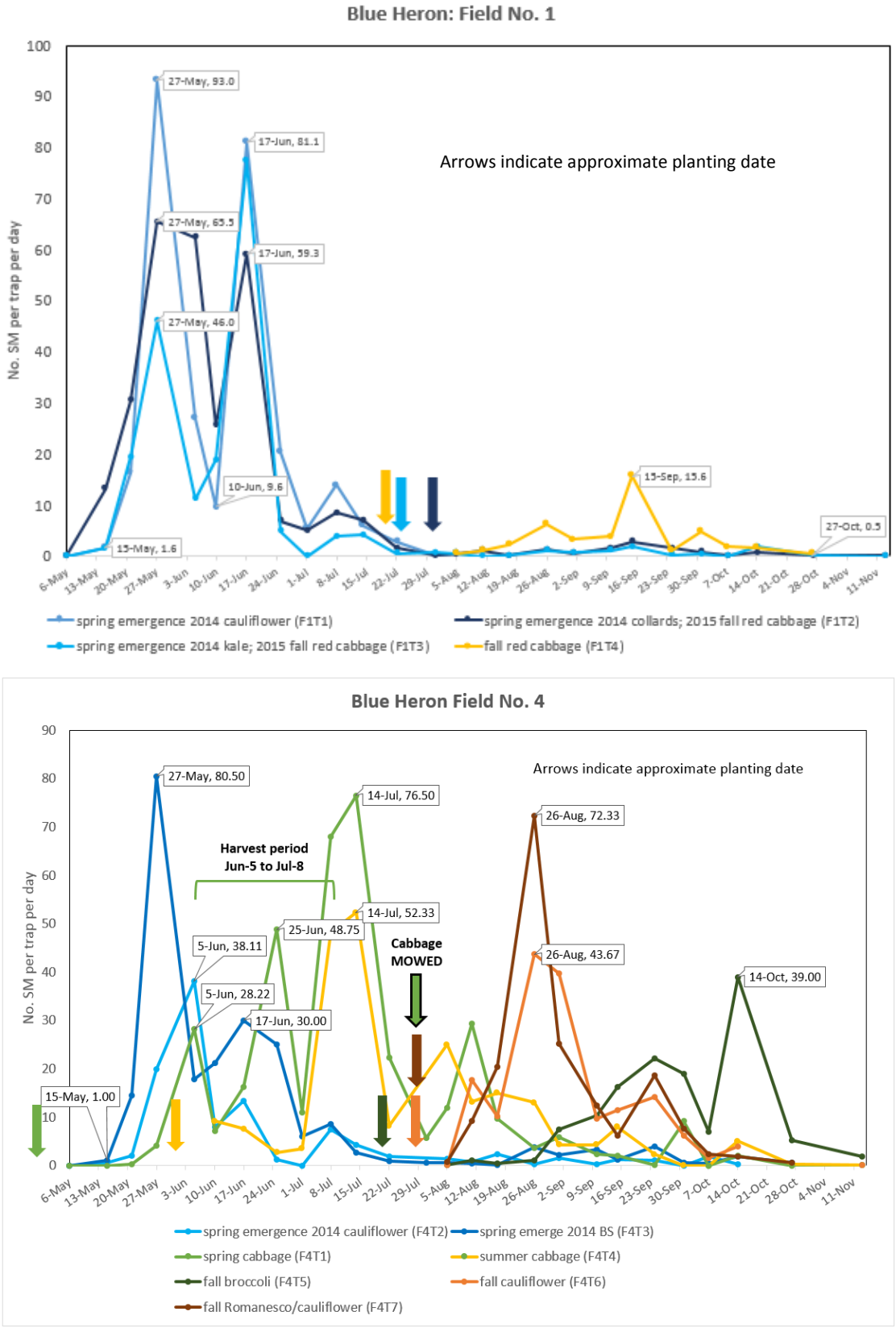
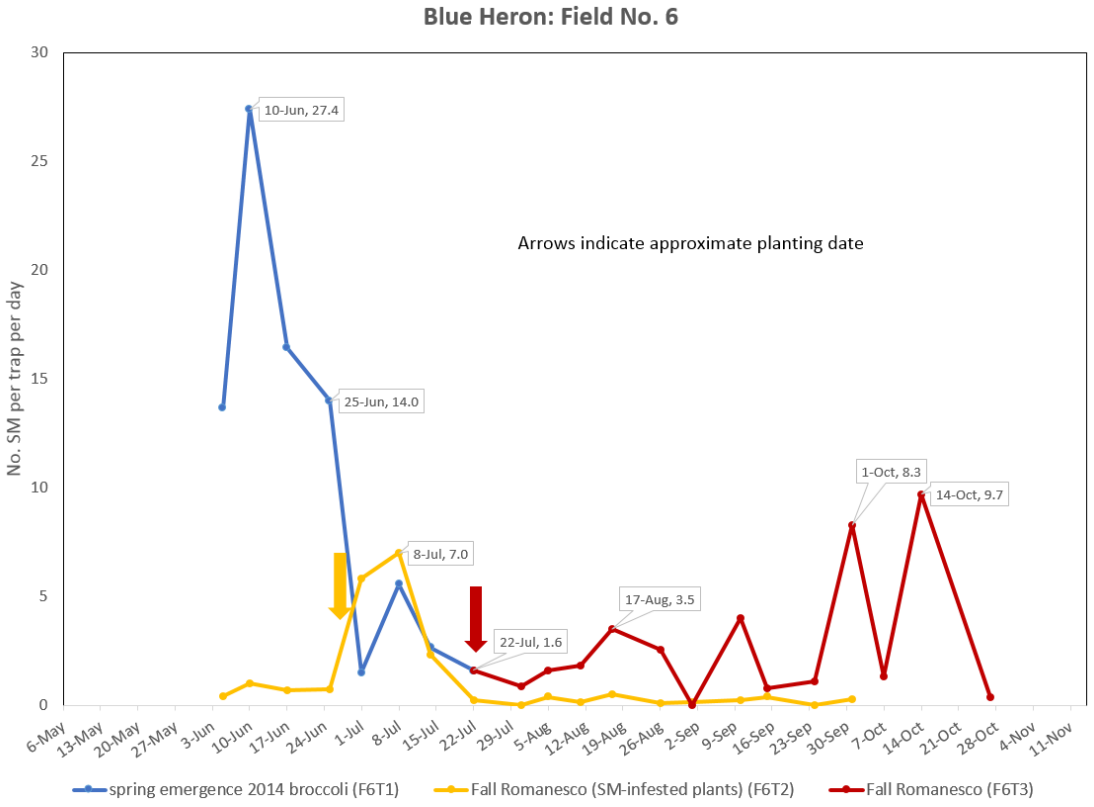


Fig. 19. Swede midge population dynamics monitored by pheromone traps at **Blue Heron in Field 1** (above) and **Field 4** (below), Lodi, NY, NY, 2015.



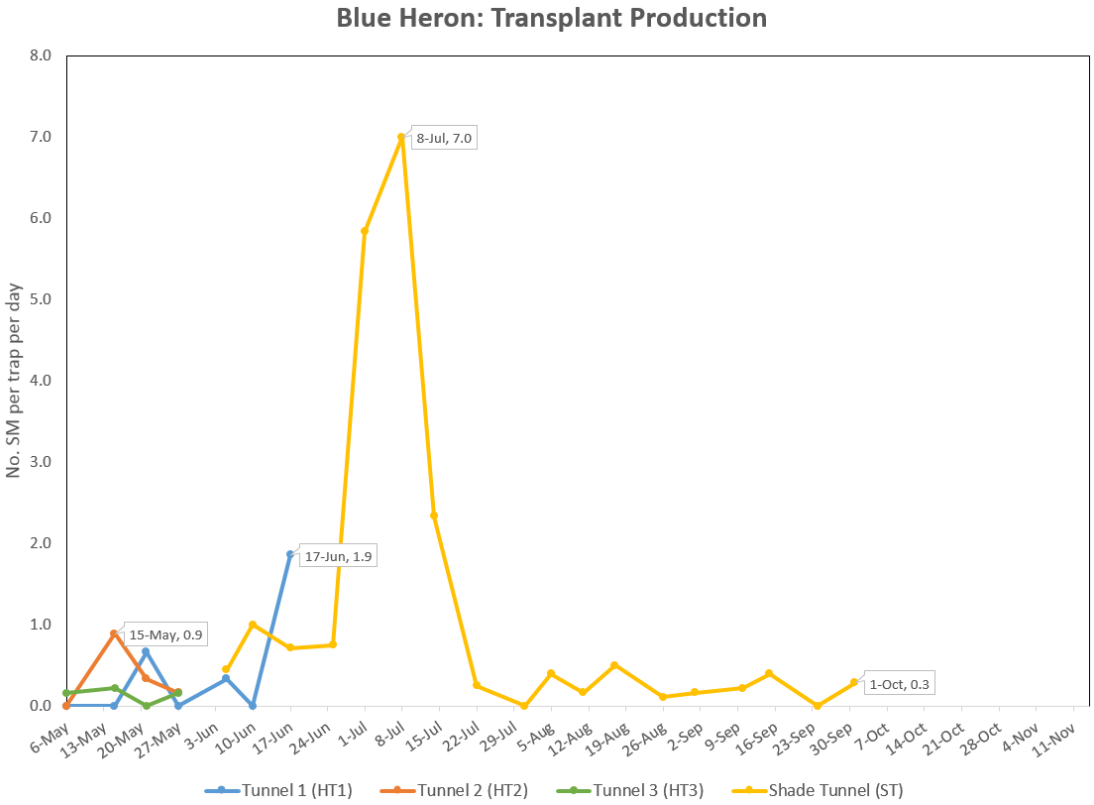


Fig. 20. Swede midge population dynamics monitored by pheromone traps at **Blue Heron in Field 6** (above) and in **transplant production** (below), Lodi, NY, NY, 2015.

Table 8. Swede midge population dynamics monitored by pheromone traps: **Spring emergence sites** on six farms, 2015.

Farm	Field	Fall 2014 SM-Infested Crop	Date of First SM Trap Capture	First Peak Capture		Second Peak Capture		Date of Last Trap Capture
				Date(s)	Maximum SM/trap/day	Date(s)	Maximum SM/trap/day	
Canticle	Main Farm – Beside Barn (Trap 2)	Kohlrabi	May-15	--	--	Jun-24	8.6	Jul-30
Canticle	Main Farm – Middle Field (Trap 3)	Brussels sprouts	May-15	May-29	7.1	Jun-19 – Jul-7	5.7	??
Canticle	Main Farm – Back field (Trap 4)	Broccoli	May-15	May-29	4.3	--	--	Jul-7
Quest Produce	Baker 2 Low Risk Site (Trap B1)	None (75 ft from SM-infested broccoli)	May-22	--	--	--	--	??
Quest Produce	Baker 2 High Risk Site (Trap B2)	Broccoli	May-15	May-22	6.0	Jun-10 – Jul-7	15.7	??
Living Acres	Back field (Trap 1)	Mixed brassicas	May-15	May-29	87.4	Jun-19	54.8	Jul-30
Fellenz	Front Field (Trap 1)	Cabbage	May-27	--	--	Jun-10 – Jun-17	4.2	Aug-11
Muddy Fingers	Small Field (Trap SF1)	Broccoli	May-13	--	--	Jun-17	18.6	Jul-31
Muddy Fingers	New Field (Trap NF1)	Mixed kale	May-21	--	--	Jun-17	13.1	Jul-31
Blue Heron	Field 1 (Trap F1T1)	Cauliflower	May-15	May-27	93	Jun-14	81	Jul-31
Blue Heron	Field 1 (Trap F1T2)	Collards	May-15	May-27 – Jun-5	65	Jun-17	59	Jul-31
Blue Heron	Field 1 (Trap F1T3)	Mixed kale	May-15	May-27	46	Jun-17	77	Aug-5
Blue Heron	Field 4 (Trap F4T2)	Cauliflower	May-15	Jun-5	38	Jun-17	13	??
Blue Heron	Field 4 (Trap F4T3)	Brussels sprouts	May-15	May-27	80	Jun-17 – Jun-25	30	Jul-31
Blue Heron	Field 6 (Trap F6T1)	Broccoli	na	--	--	Jun-10	27	??

Fig. 21. Fence line with hedgerow (behind insect exclusion netting) separating spring emergence site for swede midge (SM) (where SM-infested brassicas occurred previous fall) and current year brassica crops. In this case study, it appeared that the fence line/hedgerow served as a barrier to deter SM from finding suitable host crop. Photo: C. Hoepting.

Fig. 22. Row cover is used to protect quick-growing brassicas from swede midge until harvest in an open-sided high tunnel. Photo: C. Hall.

Table 9. Swede midge brassica crop damage evaluations at **Living Acres**, Albert Station, NY (Allegany Co.), 2015.

Crop	% SM infestation	% unmarketable	SM Damage Rating Scale (0-4)[1]	
			All Plants	Damaged Only
Main Farm: Summer red & green cabbage, mixed kale, harvest evaluation (Jul-15) (Trap 3) SM pressure: high (peaked at 20 SM/trap/day)				
Red cabbage	55.0 a[3]	25.0 a	1.42 a	2.55 a
Green cabbage	35.0 ab	12.5 b	0.65 b	1.84 ab
Winterbor kale	15.0 bc	0.0 c	0.04 c	1.06 b
Dinosaur kale	0.0 c	0.0 c	0.00 c	
P Value (α=0.05)	***0.0049***	***0.0002***	***0.0000***	***0.0093***
Data collected from 4 samples of 10 plants per cabbage and 3 samples per kale.				
Main Farm: Summer cauliflower, Brussels sprouts planting, mid-season evaluation (Jul-15) (Trap 4)				
Main Farm: Summer Chinese cabbage, mixed kale planting, mid-season evaluation (Jul-15) (Trap 5) SM pressure: moderate-high (peaked at 10 SM/trap/day)				
Crop	**% SM infestation**	**% unmarketable**	**SM Damage Rating Scale (0-3)[2]**	
			All Plants	**Damaged Only**
Brussels sprouts	83.3 a	20.0 a	1.4 a	1.6 ab
Cauliflower	70.0 ab	23.3 a	1.4 a	2.0 a
Dinosaur kale	49.0 bc	0.0 b	0.5 b	1.09 c
Winterbor kale	23.3 cd	0.0 b	0.2 bc	1.14 bc
Chinese cabbage	0.0 d	**0.0 b**	**0.0 c**	
P Value (α=0.05)	***0.0023***	***0.0000***	***0.0000***	***0.0029***
Transformation *(untransformed data presented)*		***Y=arcsin(x/100)^0.5***		
Data collected from 3 samples of 10 plants per crop type.				

[1]**Swede midge damage rating (scale 0-4): 0** = no damage; **1** = minor damage; **2**= moderate damage, reduces yield/quality but still marketable; **3**= major damage, head formation but unmarketable; **4** = severe damage, blind head.

[2]**Swede midge damage rating (scale 0-3): 0** = no damage; **1** = minor damage; **2** = moderate damage, not obvious whether yield/quality will be affected; **3** = severe damage, plant blind and will not be marketable.

[3]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test (α=0.05).

Table 10. Swede midge brassica crop damage evaluations at **Blue Heron – Field No. 4**, Lodi, NY (Seneca Co.), 2015.

Crop	% SM infestation	% unmarketable	SM Damage Rating Scale (0-4)[1]	
			All Plants	Damaged Only
Field 4: Spring mixed cabbage planting, harvest evaluation (Jul-8) (Trap F4T1) SM pressure: Very high (peaked at 76 SM/trap/day)				
Green cabbage	40 b[3]	15.0 b	0.8 b	2.0 b
Red Cabbage	100 a	71.7 a	2.8 a	2.8 a
Cone Cabbage	43 b	6.7 b	0.7 b	1.6 b
P Value (α=0.05)	***0.0001***	***0.0000***	***0.0000***	***0.0000***
Data collected from 6 samples of 10 plants per crop type.				
Field 4: Summer mixed cabbage planting, harvest evaluation (Aug-11) (Trap F4T4) SM pressure: Very high (52.3 SM/trap/day)				
			SM Damage Rating Scale (0-4)	
Green cabbage	51.7 b	3.3 b	0.8 b	1.3 b
Red Cabbage	96.7 a	60.0 a	2.4 a	2.6 a
P Value (α=0.05)	***0.0004***	***0.0001***	***0.0000***	***0.0000***
Data collected from 4 samples of 10 plants per crop type.				
Field 4: Fall planted Cauliflower and Romanesco, harvest evaluation (Sep-15) (F4T6 & F4T7) SM pressure: Very high (peaked at 72 SM/trap/day)				
			SM Damage Rating Scale (0-4)	
Cauliflower (Trap 7)*	75	45	2.1 ab	2.9
Romanesco (Trap 7)**	70	35	1.7 b	2.6
Cauliflower ***	80	37	2.0 b	2.5
Cauliflower (Trap 6)***	98	58	2.8 a	2.8
SM pressure: Very High (peaked at 44 SM/trap/day)				
P Value (α=0.05)	***NS***	***NS***	***0.0019***	***NS***
Data collected from 2*, 4** and 6*** samples of 10 plants per crop type.				
Field 4: Fall planted broccoli, mid-season evaluation (Sep-15) (F4T5) SM pressure: Very high (peaked at 39 SM/trap/day)				
			SM Damage Rating Scale (0-3)	
Broccoli	97	23	1.8	1.9
Data collected from 6 samples of 10 plants per crop type.				

[1]**Swede midge damage rating (scale 0-4): 0** = no damage; **1** = minor damage; **2**= moderate damage, reduces yield/quality but still marketable; **3**= major damage, head formation but unmarketable; **4** = severe damage, blind head.

[2]**Swede midge damage rating (scale 0-3): 0** = no damage; **1** = minor damage; **2** = moderate damage, not obvious whether yield/quality will be affected; **3** = severe damage, plant blind and will not be marketable.

[3]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test (α=0.05).

Table 11. Swede midge brassica crop damage evaluations at **Blue Heron - Fields No. 1 and 6**, Lodi, NY (Seneca Co.), 2015.

Crop	% SM infestation	% unmarketable	SM Damage Rating Scale (0-4)[1]	
			All Plants	Damaged Only
Field 1: Fall planted red cabbage planting, harvest evaluation (Sep-15) (Trap F1T3) SM pressure: low (peaked at 3 SM/trap/day				
Red Cabbage	25	2	0.4	1.5
Data collected from 6 samples of 10 plants per crop type.				
Field 1: Fall planted red cabbage planting, mid-season evaluation (Sep-15) (Trap F1T4) SM pressure: moderate-high (peaked at 15 SM/trap/day)				
			SM Damage Rating Scale (0-3)[2]	
Red Cabbage	48	6	0.8	1.7
Data collected from 6 samples of 10 plants per crop type.				
Field 6: Fall broccoli planting, harvest evaluation (Oct-14) (in bed beside Trap F6T1) SM pressure: moderate-high (peaked 9.7 SM/trap/day)				
			SM Damage Rating Scale (0-4)[1]	
Broccoli	55	25	1.4	2.5
Data collected from 4 samples of 10 plants per crop type.				

[1]**Swede midge damage rating (scale 0-4): 0** = no damage; **1** = minor damage; **2**= moderate damage, reduces yield/quality but still marketable; **3**= major damage, head formation but unmarketable; **4** = severe damage, blind head.

[2]**Swede midge damage rating (scale 0-3): 0** = no damage; **1** = minor damage; **2** = moderate damage, not obvious whether yield/quality will be affected; **3** = severe damage, plant blind and will not be marketable.

Table 12. Swede midge brassica crop damage evaluations at **Canticle**, Allegany, NY (Cattaraugus Co.), 2015.

Crop	% SM infestation	% unmarketable	SM Damage Rating Scale (0-3)[1]	
			All Plants	Damaged Only
Main Farm Middle Field: Summer mixed brassica planting, harvest evaluation (Jul-15) (Trap 5) SM pressure unknown				
Winterbor kale	20 bc[3]		0.2 b	1.0 b
Purple kale	30 b		0.2 b	1.0 b
Red Russian kale	75 a		1.1 a	1.4 a
Dinosaur kale	5 c		0.3 b	1.0 b
P Value (α=0.05)	***0.0001***		***0.0000***	***0.0006***
Data collected from 4 samples of 10 plants per crop type.				
Main Farm Middle Field: Summer mixed cabbage planting, mid-season evaluation (Jul-15) (Trap 5) SM pressure unknown				
			SM Damage Rating Scale (0-3)[1]	
Green cabbage	8.3	0.0	0.1	1.1 b
Red Cabbage	8.3	4.0	0.2	2.2 a
Savoy cabbage	0.0	0.0	0.0	--
P Value (α=0.05)	***NS***	***NS***	***NS***	***0.0332***
Data collected from 6 samples of 10 plants per crop type.				
Main Farm Front Field: Fall mixed kale planting, mid-season evaluation (Sep-17) (Trap 6) SM pressure: medium-high (peaked at 13.4 SM/trap/day)				
			SM Damage Rating Scale (0-3)[1]	
Winterbor kale	0 c		0.0 c	--
Red Curly kale	0 c		0.0 c	--
Red Russian kale	82 a		1.2 a	1.5 a
Dinosaur kale	0 c		0.0 c	--
White Russian kale	75 a		1.2 a	1.6 a
Rainbow lacinato kale	47 b		0.5 b	1.0 a
P Value (α=0.05)	***0.0000***		***0.0000***	***0.0119***
Data collected from 4 samples of 10 plants per crop type.				
Main Farm Back Field: Fall broccoli planted beside Brussels sprouts netting trial (Oct-8) (Trap Fall Trial) SM pressure: high (peaked at 20.2 SM/trap/day)				
			SM Damage Rating Scale (0-4)[2]	
Broccoli	92	60	2.7	2.9
Data collected from 6 samples of 10 plants per crop type.				

[1]**Swede midge damage rating (scale 0-3): 0** = no damage; **1** = minor damage; **2** = moderate damage, not obvious whether yield/quality will be affected; **3** = severe damage, plant blind and will not be marketable.

[2]**Swede midge damage rating (scale 0-4): 0** = no damage; **1** = minor damage; **2**= moderate damage, reduces yield/quality but still marketable; **3**= major damage, head formation but unmarketable; **4** = severe damage, blind head.

[3]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test (α=0.05).

Table 13. Swede midge brassica crop damage evaluations at **Quest Produce**, Almond, NY (Allegany Co.), 2015.

Crop	% SM infestation	% unmarketable	SM Damage Rating Scale (0-4)[1]	
			All Plants	Damaged Only
Sexton Farm: Fall mixed kale planting, harvest evaluation (Oct 8) (Trap S2) SM pressure: low (peaked at 2.4 SM/trap/day)				
Red Russian kale	100 a[2]	53.7 a	2.8 a	2.8 a
White Russian kale	100 a	30.0 b	2.3 b	2.4 a
Winterbor kale	17.5 b	0.0 c	0.2 c	1.0 b
Lacinato	16.3 b	0.0 c	0.15 c	1.0 b
Red curly kale	3.3 b	0.0 c	0.03 c	1.0 b
P Value (α=0.05)	***0.0000***	***0.0001***	***0.0000***	***0.0000***
Data collected from 4 samples of 10 plants per crop type. Only 3 and 2 samples per red curly kale and white Russian kale, respectively..				

[1]**Swede midge damage rating (scale 0-4): 0** = no damage; **1** = minor damage; **2**= moderate damage, reduces yield/quality but still marketable; **3**= major damage, head formation but unmarketable; **4** = severe damage, blind head.

[2]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test (α=0.05).

Table 14. Swede midge brassica crop damage evaluation at **Muddy Fingers**, Hector, NY (Schuyler Co.), 2015.

Crop	% SM infestation	% unmarketable	SM Damage Rating Scale (0-3)[1]	
			All Plants	Damaged Only
Small field: Spring mixed brassica planting, mid-season evaluation (Jul-8) (Trap SF2) SM pressure: moderate-high (peaked at 8.4 SM/trap/day)				
Red Brussels sprouts	55.3		0.7 a[2]	1.3 ab
Peacock kale	36.7		0.6 ab	1.5 a
Green Brussels sprouts	46.7		0.5 ab	1.1 ab
Dinosaur kale	30.0		0.3 bc	1.0 b
Green Brussels sprouts[4]	30.0		0.3 bc	1.0 b
Winterbor kale	3.3		0.1 c	2.0 a
P Value (α=0.05)	***NS***		***0.0009***	***0.0360***
Transformation[3]	--		Sqrt(x)	Log(x+1)
Data collected from 3 samples of 10 plants per crop type.				

[1]**Swede midge damage rating (scale 0-3): 0** = no damage; **1** = minor damage; **2** = moderate damage, not obvious whether yield/quality will be affected; **3** = severe damage, plant blind and will not be marketable.

[2]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test (α=0.05).

[3]Dataset was not normal and was transformed using described equation, non-transformed values are presented.

[4]This row of Brussels sprouts was on the opposite side of the field.

Table 15. Evaluation of **insect exclusion netting with various mulches** on **ground previously infested with swede midge (SM) and never cropped to brassicas** for control of SM in **spring planted broccoli, Quest Farm Produce**, Almond, NY, 2015.

High Risk Site: on ground that had SM infestation in broccoli in fall 2014						
Treatment	**Total No. SM captured in traps/12 weeks (May-7 to Jul-15)**	**Harvest (Jul-15)**				
		Swede Midge (% plants infested)	**% Unmarketable due to SM[2]**	**Average SM damage rating (Scale: 0-4)[1] of infested plants**	**% Unmarketable due to heat stress[3]**	**Comments**
Bare ground – Open air	575	90	90	3.3	0	Multiple shoots & branching low to the ground
Bare ground **+ Insect Exclusion Netting**	411	95	95	3.3	0	
Straw Mulch **+ Insect Exclusion Netting**	804	89	89	3.4	0	Imported cabbage worm
Black plastic mulch **+ Insect Exclusion Netting**	301	33	33	2.8	9.5	
Low Risk Site: on ground not cropped to Brassicas in 2014, ~ 75 ft from high risk site						
Bare ground – Open air	220	67	67	3.1	0	Multiple shoots & branching low to the ground
Bare ground **+ Insect Exclusion Netting**	31	0	0	0	0	Delayed maturity compared to plastic mulch
Straw Mulch **+ Insect Exclusion Netting**	2	0	0	0	17	Imported cabbage worm
Black plastic mulch **+ Insect Exclusion Netting**	0	0	0	0	35	

[1]**Swede midge damage rating (scale 1-4):** 1 = minor damage, no effect on plant; 2 = moderate damage, does not affect marketability, but reduces yield and/or quality; 3 = plant produced a head, but it is unmarketable; 4 = bind head.

[2]Unmarketable due to SM damage = 3 and 4 on SM damage rating scale.

[3]Heat stress includes: inner leaves in head, yellow/brown beading; premature bolting, etc.

Table 16. Evaluation of **insect exclusion netting with various mulches** for control of swede midge in **spring planted broccoli, Muddy Fingers Farm,** Hector, NY (Schuyler Co.), 2015.

Treatment	Variety[1]	SM Trap Catches (No. SM per 7.8 weeks)[2] Apr-30 to Jun-25	Harvest (Jun-25)					
			% Swede Midge Infestation	Worm Damage Rating (scale: 0-3)[2]	Flea Beetle Damage Rating (scale 0-3)[2]	Plant height (inch)	Average Head Size (lb)	Marketable Yield (per 100 ft of bed)
Bare ground Open air	Aracadia	19	18.7 b[3]	2.0 a	2.0 b	40.2	1.17	35.0
	Diplomat	59	76.5 a			25.4	0.79	27.5
Bare ground + insect exclusion netting	Aracadia	0	0.0 c	1.0 b	0.0 b	36.4	1.18	107.0
	Diplomat	1	0.0 c			34.3	0.95	53.8
Black plastic mulch + insect exclusion netting	Diplomat	0	1.0 b	1.0 b	0.0 b	34.6	0.87	64.0
Landscape fabric + insect exclusion netting	Aracadia	1	0.0 c	0.75 b	0.0 b	39.7	1.12	94.0
	Diplomat	1	0.0 c			29.5	0.97	56.2
Hay mulch + insect exclusion netting	Diplomat	3	0.0 c	0.75 b	0.0 b	30.7	1.00	61.4
P Value (α=0.05)		--	***0.0397***	***0.0026***	***0.0000***	--	--	--

[1]One row of trial was planted to variety, Arcadia, while other rows were Diplomat (see Fig. 12).

[2]**Insect Damage Rating (Scale 0-3):** 0 = no damage; 1 = minor damage; 2 = moderate damage; 3 = severe damage.

[3]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test, $p<0.05$.

Fig. 23. Effect of insect exclusion netting and mulch on spring-planted broccoli, Muddy Acres, 2015. Left: Broccoli under insect exclusion netting was larger and had healthier foliage than adjacent broccoli grown on bare ground in the open air, which suffered from cold injury (yellow leaves) and flea beetle feeding (shot holes). Broccoli grown under insect exclusion netting with black plastic mulch (middle) reached maturity earlier than the broccoli grown with hay mulch (right). Photos: C. Hall.

Table 17. Evaluation of **insect exclusion netting with various mulches** for control of swede midge in **late summer broccoli**, Muddy Fingers Farm, Hector, NY, 2015.

Treatment	SM Trap catches (No. SM per 8.7 weeks) Jul-1 to Aug-26	Harvest (Aug-26)			
		% SM	% Unmarketable (rating 3 & 4)	Average SM damage rating[1] of infested plants (scale: 0-4)	Comments
Black plastic mulch – Open air	107	100	85	3.3	
Black plastic mulch + Insect Exclusion Netting **Rep 1**	5	0	0	0.0	First treatment to be ready for harvest
Black plastic mulch + Insect Exclusion Netting **Rep 2**	1	0	0	0.0	3% plants with heat stress; first treatment ready for harvest
Landscape fabric – Open air	121	92	69	3.3	
Landscape fabric + Insect Exclusion Netting **Rep 1**	5	0	0	0.0	Developmentally delayed compared to biotelo mulch; 3% aphids
Landscape fabric + Insect Exclusion Netting **Rep 2**	0	0	0	0.0	Developmentally delayed compared to biotelo mulch; 8% aphids
Hay mulch – open air	332	100	50	3.1	
Hay mulch + Insect Exclusion Netting	21	6	4	2.5	8% heat stress; 3% aphids; healthier and bigger compared to landscape fabric

[1]**Swede midge damage rating (scale 1-4):** 1 = minor damage, no effect on plant; 2 = moderate damage, does not affect marketability, but reduces yield and/or quality; 3 = plant produced a head, but it is unmarketable; 4 = bind head.

Table 18. Evaluation of **insect exclusion netting with biodegradable plastic mulch** for control of swede midge in **fall planted Brussels sprouts**, Canticle Farm, Allegany, NY (Cattaraugus Co.), 2015.

Treatment	SM Trap catches (No. SM per 15.3 weeks)[4] Jun-19 to Oct-15	Harvest (Oct-15)						
		Swede Midge Damage			Plant height (inch)	No. sprouts per plant	Mean Sprout diameter (inch)	No. non-SM blind sprouts per plant
		% SM infestation	Rating (0-4)[1] All Plants	Rating (0-4)[1] Damaged Plants only				
Bare ground Open air	597	60.0 a[2]	0.6 a	1.0	21.8 b	58.5 b	1.85 a	4.3 a
Bare ground + insect exclusion netting	8	3.6 b	0.0 c	1.0	28.1 a	61.4 b	1.47 b	0.0 c
Black plastic mulch Open air	--	42.5 a	0.4 b	1.0	19.1 c	63.2 ab	1.19 c	2.7 b
Black plastic mulch + insect exclusion netting	2	2.5 b	0.0 c	1.0	27.1 a	71.8 a	0.80 d	0.0 c
P Value	**--**	***0.0125***	***0.0000***	**--**	***0.0000***	***0.0235***	***0.0000***	***0.0000***
Transformation[3]	--	--	--	--	--	--	--	Log(x+1)
Sample size (per rep)	--	2 samples of 10 plants	2 samples of 10 plants				10 sprouts per plant on 10 plants	2 samples of 10 plants

[1]**Swede midge damage rating (scale 0-4): 0** = no damage; **1** = minor damage; **2**= moderate damage, reduces yield/quality but still marketable; **3**= major damage, head formation but unmarketable; **4** = severe damage, blind head.

[2]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test (α=0.05).

[3]Dataset was not normal and was transformed using described equation, non-transformed values are presented.

[4]Average of rep 1 and 2.

Fig. 24. Brussels sprouts grown under insect exclusion netting (top left) were taller with delayed maturity and without Alternaria leaf spot (bottom left) compared to plants grown in the open-air (top and bottom right), Canticle insect exclusion netting trial in fall Brussels sprouts, 2015. Photos: C. Hoepting

Fig. 25. Left: Blind Brussels sprout caused by swede midge. Note, diagnostic brown corky scarring. Right: Blind Brussels sprout not caused by swede midge. Note, the absence of corky scarring. Photos: C. Hoepting.

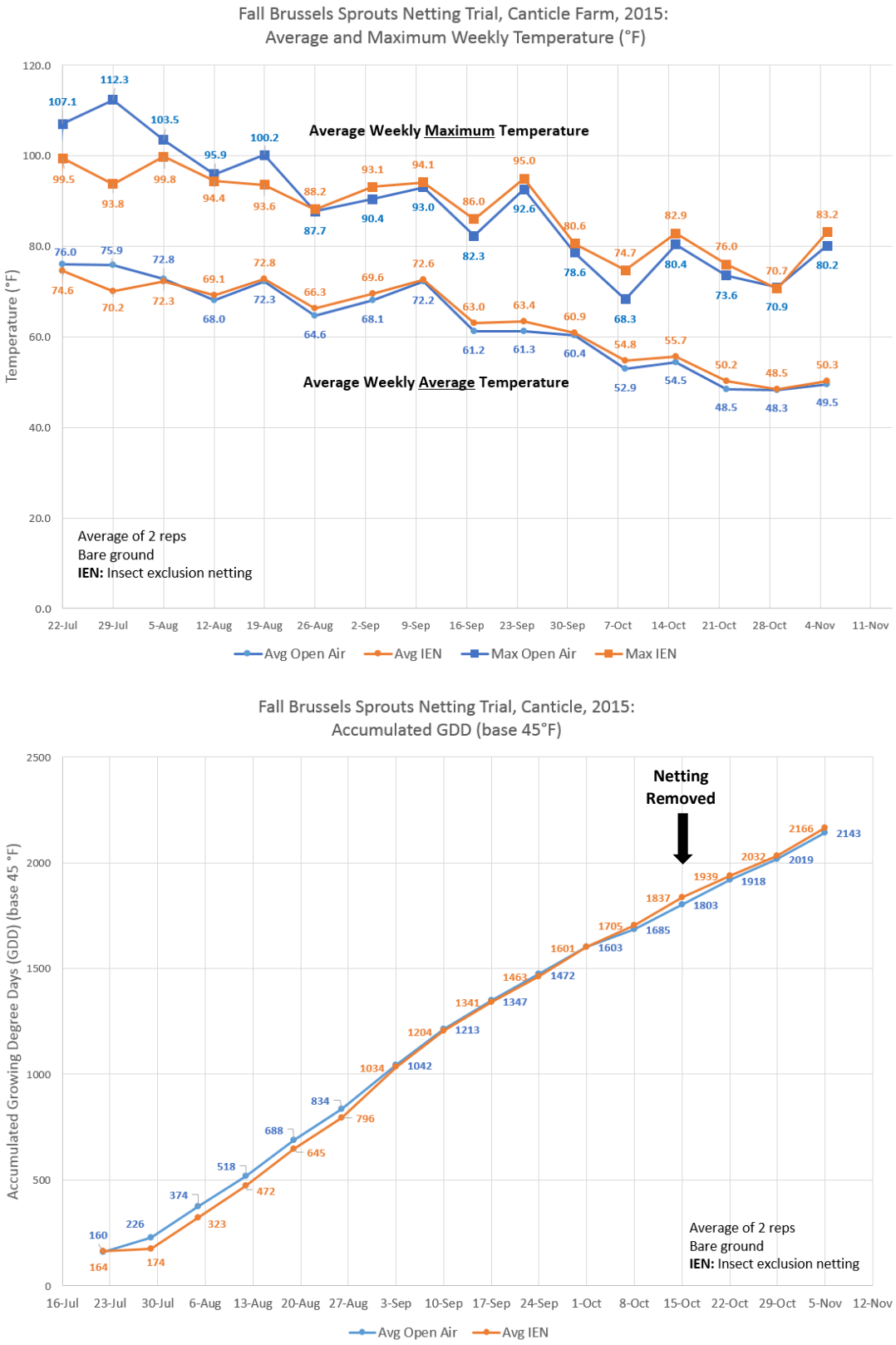


Fig. 26. Average and maximum weekly temperature (above) and accumulated growing degree days (base 45 °F) between bare ground open air (blue) and under insect exclusion netting (orange) in Fall Brussels sprouts netting trial, Canticle Farm, Allegany, NY, 2015.

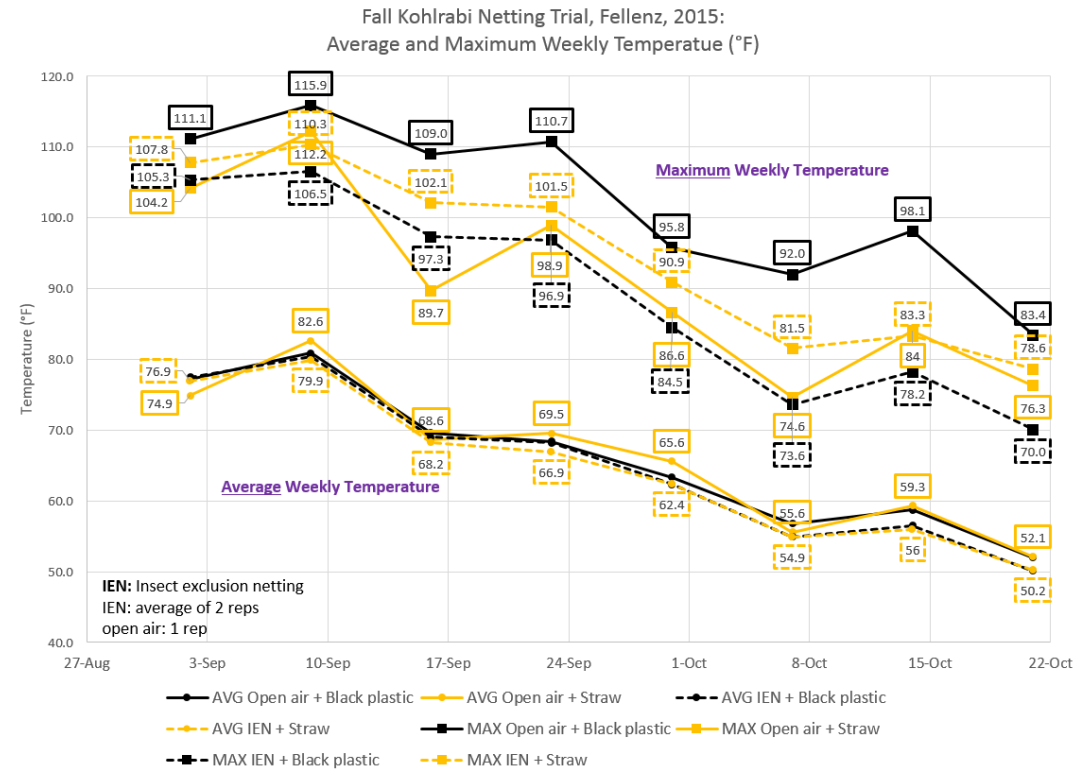
Table 19. Evaluation of **insect exclusion netting with various mulches** for control of swede midge in **Fall kohlrabi**, Fellenz Family Farm, Phelps, NY, 2015.

Treatment	**SM Trap catches (No. SM per 8 weeks)** [1] Sep-1 to Oct-27	**Harvest (Oct-27)**		
		Swede Midge (SM)	**Imported Cabbage Worm (ICW)**	
		% Infestation	**% Infestation**	**Average Damage Rating (Scale: 0-3)**[2]
Black Plastic Mulch Open Air	1	0.0	99.1 a[3]	1.0 a
Black Plastic Mulch **+ Insect Exclusion Netting**	0	0.0	2.5 c	0.01 c
Hay Mulch Open Air	4	0.0	96.2 a	1.1 a
Hay Mulch **+ Insect Exclusion Netting**	0	0.0	21.9 b	0.14 b
P Value (α=0.05)	**--**	**--**	***0.0000***	***0.0000***
Sample size (per rep)		2 reps, 2 samples of 10 plants per rep		

[1]Average of two reps.

[2]**Insect Damage Rating (Scale 0-3):** 0 = no damage; 1 = minor damage; 2 = moderate damage; 3 = severe damage.

[3]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test, $p<0.05$.



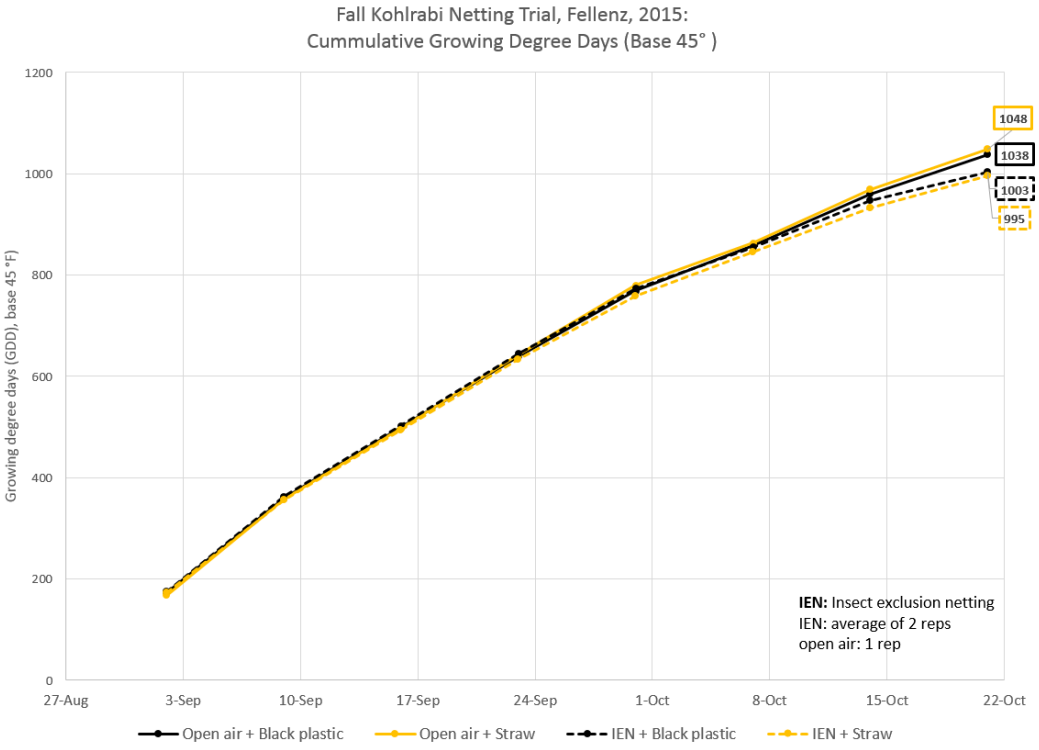


Fig. 27. Average and maximum weekly temperature (above) and accumulated growing degree days (base 45 °F) between open air (solid) and under insect exclusion netting (dashed) with straw (yellow) and black plastic (black) mulches in Fall Kohlrabi netting trial, Fellenz Family Farm, Phelps, NY, 2015.

Table 21. Economic feasibility of using insect exclusion netting (IEN) for control of swede midge, Muddy Fingers Spring Broccoli Netting Trial, Hector, NY, 2015.

Treatment	Per Bed: 100' x 4'								
	Marketable Yield (lb)	Sales Revenue ($)[1]	Cost of Inputs for SM Protection ($)				Net		
			Netting	Mulch	Labor	Total	Single Use[4]	Double Use[5]	Triple Use[6]
Bare ground	27.5	**$82.50**			$30 HW[2]	**$30.00**	**$52.50**	**$52.50**	**$52.50**
Bare ground + IEN	53.8	**$161.40**	$175.61		$60 N,HW	**$235.61**	**-$74.21**	**$13.59** IEN	**$42.85** IEN
Black Plastic Mulch + IEN	64.0	**$192.00**	$175.61	$5.225	$33 LM,N	**$213.84**	**-$21.84**	**$66.96** IEN	**$95.96** IEN
Landscape fabric + IEN	56.2	**$168.60**	$175.61	$18.65	$33 LM,N	**$227.26**	**-$58.66**	**$38.46** IEN + mulch	**$70.82** IEN + mulch
Hay mulch + IEN	66.4	**$184.20**	$175.61	$7.00	$48 LM,N,HW[3]	**$230.61**	**-$46.41**	**$41.39**	**$70.65**

[1]Using a price of $3.00/lb.

[2]HW: hand weed; N: set up netting; LM: lay mulch.

[3]Some weed escapes expected with hay mulch, light hand weeding @ $15.

[4]Single use of netting and mulch.

[5]Double use of netting and mulch. Spread cost over 2 years = $87.80/year for netting and $9.32/year for landscape fabric.

[6]Triple use of netting and landscape fabric. Spread cost over 3 years = $58.53/year for netting and $6.21/year for landscape fabric.

Table. 22. Cost of insect exclusion netting and mulch for control of swede midge on 4-foot wide beds with 4-foot tall hoops.

Material	**Per bed 100 ft x 4 ft**	**Reusable?**
Insect exclusion netting 25 gr: 14' x 820' roll = $1440	$175.61	Depends[1]
10-ft electrical conduit to make hoops, 1 every 4 feet: need 25 @ $2.61 each	$65.25	yes
Fiberglass rod posts to anchor hoops, 1 post per hoop (cut in half): need 25 @ $2.99 each	$74.75	yes
Clips to hold netting onto hoops, 5 per hoop: need 125 @ $0.522 each	$65.62	yes
TOTAL Cost of Netting and Supplies	**$381.23**	~ $200 (hoops, stakes & clamps)
Labor @ $10/h: to set up netting: ~2-4 man hours[1]	$20-$40	no
Mulches: BioTelo black plastic mulch 6 mil: 4' x 4000' @ $209 per roll	$5.225	no
Landscape fabric: 4' x 300' @ $56 per roll	$18.65	yes[3]
Hay mulch: $14 per round bale for 2 x 100' beds	$7.00	no
Labor @ $10/h to lay mulch: 20 min	$3.00	no
Labor @ $10/h to hand weed: 3 hour	$30.00	

[1]Care must be taken not to tare it when removing clamps. When it is secured to ground with sod or soil, netting tends to rip upon removal. Should work for at least 2 broccoli plantings in same season.
[2]Most labor-intensive task is securing sides of netting to ground. Wind may i9nterfere with and add to the time it takes to apply netting over hoops.
[3]Landscape fabric is more durable than plastic mulch, but it will have pre-poked holes already in.