Lorsban is Banned: How to Control Cabbage Maggot in Brassicas Now?

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Cabbage maggot (CM) feeds on brassica seedlings by tunneling into the stem of the plant just below the soil line (Fig. 1). Their feeding can result in unsightly and unmarketable produce in the case of root brassicas like turnips, and in stunting, reduced stand, and reduced yield in head and stem brassicas like cabbage and broccoli (Fig. 2). Lorsban and other formulations containing the active ingredient chlorpyrifos were the first line of defense for control of cabbage maggot in several brassica crops, because 1) at ~$10 per acre, it was affordable, and 2) it was easy to apply and avoided worker exposure as a directed spray at the base of the plant.

Figure 1. Cabbage maggot feeding on stem of cabbage plant just below the soil line. Photo by Faruque Zaman, CCE Suffolk County

Figure 2. Economic damage caused by cabbage maggot in root brassicas (left) and in head and stem brassicas (right). Root brassicas have no tolerance for cabbage maggot feeding, because it results in unmarkable produce. In stem and head brassicas such as cabbage, cabbage maggot feeding only results in unmarketable damage when it kills or severely stunts the plants. Photos: Ben Werling, MSU (left), and Faruque Zaman, CCE Suffolk County (right).

Lorsban is Banned in New York and Nationwide

Unfortunately, Lorsban and all of its generic products for food and feed uses were banned in New York as of July 31, 2021, and in the United States as of February 28, 2022. For more information on the U.S. ban, see: https://pestmanagement.rutgers.edu/chlorpyrifos-revocation-of-all-food-tolerances-effective-february-28-2022/

In the absence of Lorsban and other chlorpyrifos-containing insecticides, NY brassica growers have 6 products belonging to 4 chemical classes available to manage cabbage maggot (Table 1).

2022 Top Picks to Use Instead of Lorsban for Cabbage Maggot Control in Brassicas

1. Mustang Maxx Directed Spray at Plant Base

In a 2021 Cornell insecticide trial in Riverhead (Long Island), Mustang Maxx 4 fl oz/A applied 4 times as a directed spray (DS) at the base of cabbage plants (5 days after transplanting, then weekly for 3 weeks) resulted in **72% reduction in CM-infested plants** compared to the untreated, which had 57% infested (Table 2). **At ~$1/fl oz, four applications of Mustang Maxx 4 fl oz would cost ~$16/A, which is by far the most affordable alternative to Lorsban for the level of control it provides.**

The **disadvantage of Mustang Maxx is that multiple foliar applications are required for effective control**. A study in Michigan in turnips showed a reduction in cabbage maggot control when Mustang Maxx was applied twice during peak spring flight of CM compared to when it was applied 6 times weekly from first to last emergence of overwintering flies (as indicated by a predictive growing degree day model).

Currently, Mustang Maxx is only labeled for control of cabbage maggot in radish, rutabaga and turnips. However, it is labeled on head and stem brassicas (e.g. cabbage, broccoli, Brussels sprouts, etc.) for management of other insect pests including worms, thrips, and flea beetles. **Cornell is working with FMC to acquire a Section 2(ee) label expansion for both Mustang Maxx and Hero** (a.i. in Mustang Maxx + bifenthrin) to include use against cabbage maggot in head and stem brassicas. Ideally, both will be available soon for the 2022 growing season.

2. Verimark Tray Drench

In a 2021 Cornell trial in Riverhead, Verimark 13.5 fl oz/A applied as a tray drench (TD) resulted in **~56% reduction in CM-infested plants** compared to the untreated (57% CM-infested). In 2020, Verimark 13.5 fl oz/A TD treatment was followed by a DS treatment 14 days after planting, which resulted in 55% reduction in CM-infested plants under very high pressure (untreated: 91% CM-infested). CM control using these Verimark TD treatments was not significantly different than control provided by Lorsban in 2020 and Mustang Maxx in 2021 (Table 2). **Verimark 13.5 fl oz/A TD also provided excellent control of worm pests and flea beetles** in Riverhead trials (data not shown). **While Verimark 13 fl oz/A costs ~$105/A and might be considered too expensive for cabbage maggot control alone, growers should consider the 4-6 weeks of worm pest and flea beetle control that it will also provide.** If worm and flea beetle pressure are likely to require control, Verimark may be an excellent and affordable choice. If a follow up DS application is warranted, the cheaper Mustang Maxx could suffice. Verimark is **relatively safe for handlers** as it does not carry a signal word and has minimum PPE requirements (e.g. handlers do not need to wear gloves).

Tray drench application can be tricky.

The Verimark label requires that the rate/A be divided by the number of plants/A, which is then multiplied by the number of plants per tray to figure out how much Verimark to apply per plug transplant tray. The label suggests that watering be stopped 24 hours before treatment of trays and that applicator figures out how much water volume per tray is required to thoroughly drench the tray without the solution running out the bottom. The Verimark solution is applied over the foliage and may be followed with a second application of water to wash it off the leaves into the soil media; again without having the solution run out the bottom of the tray). **Treated transplants should be transplanted within 72 hours of treatment.** Since plant population can vary considerably, the rate of Verimark 13.5 fl oz/A applied to each individual plant could range from 0.0006 fl oz (21,780 plants/A with 24" row x 12" plant spacing) to 0.0018 fl oz (7,260 plants/A, 36" row x 24" plant spacing). In the Riverhead trials, Verimark was applied at 0.0008 fl oz/plant.

Tray drench is the best application method.

A California study showed that Verimark 13.5 fl oz/A DS application had 3-times more CM-infested plants than the TD application (Table 4). This **trend of much improved cabbage maggot control with TD over DS application** was also observed in the same trial with Radiant 10 fl oz/A (Table 4) and in several other trials (data not shown). In a 2021 Oakfield on-farm trial, Verimark 6.5 fl oz/A DS had numerically 30% more CM-infested plants than the 6.5 fl oz/A rate transplant water (TW) application, although neither were significantly better than the untreated (Table 3). In other studies (data not shown), TD applications of Verimark had less CM infestation/damage than TW applications. In the 2021 Oakfield trial, DS application of high rate of Verimark 13.5 fl oz/A ($105/A) had numerically 43% fewer CM-infested plants than the 6.5 fl oz/A rate ($51/A), suggesting that **rate matters. Overall, best control of cabbage maggot with Verimark is achieved with 13.5 fl oz/A applied as a try drench.**

Other Products

Radiant SC

This product is labeled for application as a **directed spray at the plant base (DS) using 100 gpa**. Radiant is labeled for suppression only of cabbage maggot. In Cornell trials, **Radiant DS resulted in 22 to 51% reduction in CM-infested plants compared to the untreated** with no rate relationship between 5 – 10 fl oz/A (Table 2, 3). It was generally not as good as Lorsban, but Radiant 5-10 fl oz/A DS was **similar to Verimark 13.5 fl oz/A DS** in a 2021 Oakfield trial (Table 3) and in a California trial (Table 4). Radiant 10 fl oz/A (~$70/A) is slightly cheaper than Verimark 13.5 fl oz/A and **should provide worm control**. Radiant **will not control flea beetles**.

Coragen

This product is also labeled for suppression only of cabbage maggot. In a 2021 Oakfield on-farm trial, **Coragen 5 fl oz/A in transplant water (TW) was not significantly different than the untreated** for CM-infested plants (Table 3). In other trials (data not shown), it was generally less effective than Verimark. However, Coragen is **one of the more affordable options at ~$11/A (5 fl oz)**. It also **provides worm control, does not carry a signal word and requires minimal PPE**. Coragen **will not control flea beetles**.

Diazinon

In a 2021 Oakfield on-farm trial, Diazinon AG500 3 qt/A applied in transplant water (TW) resulted **in 93% reduction of CM-infested plants** compared to the untreated and was **by far the best treatment with the longest residual activity in any of the Cornell trials** (Table 3). The major disadvantage of this treatment is that it **poses significant risk for worker exposure and requires extensive PPE** including respirator with organic vapor cartridges, chemical resistant footwear, chemical resistant gloves made of barrier laminate or viton, and goggles/face shield. Unfortunately, the **safer option of applying Diazinon AG500 3 qt/A as a broadcast spray pre-plant incorporated to 3-4 inches (PPI), was not effective** (Table 3). It also is **federally-restricted use**, which means that the operator of the tractor pulling the transplanter must be a certified pesticide applicator. **Diazinon AG500 3 qt/A TW resulted in 46% stunting 25 days after planting** in the 2021 Oakfield trial (data not shown). Although the plants eventually grew out of the stunting, it seems backwards to apply a treatment that may cause stunting in order to protect the crop from an insect that can cause stunting. Diazinon costs ~ $60/A and **does not control other common insects like flea beetles and worms**.

Head and Stem Brassicas Can Tolerate Some Cabbage Maggot

Root brassicas have a low tolerance for cabbage maggot, because the feeding damage renders radishes and turnips unmarketable. Alternatively, in head and stem brassicas, unless plants are severely infested to the extent that stand is reduced or stunting reduces marketable yield, **minor CM feeding damage does not cause yield reduction or economic losses** (Fig. 3). In the Cornell trials, even though % CM-infested plants in many of the treatments was not significantly lower than in the untreated, the severity of the root damage was significantly less than the untreated and generally minor (e.g. < 3 out of 10 scale) (Table 2). In the 2021 Oakfield trial, less than 10% of the cabbage plants were stunted from CM in any treatment (Table 3). For example, even if a product is not perfect at controlling CM and kills only 65% of the maggots, 2 or 3 maggots feeding per stem is much less damaging than 6 or 9. Therefore, **unless cabbage maggot pressure is high, chances are that any of the products listed in Table 1 would provide adequate control of CM in head and stem brassicas**, provided they are applied correctly.

Figure 3. Minor feeding damage (left) from cabbage maggot is not likely to impact yield of head and stem brassicas, while severe feeding damage (right) will. Photo by Christy Hoepting, CCE Cornell Vegetable Program

Target Treatment to the Base of the Plant, Just Below the Soil Line

Cabbage maggot eggs are deposited at the base of the plant at the soil line. Once they hatch they begin feeding on the stem at the soil line and work their way down. In plug transplants, the majority of the cabbage maggots are found in the root ball. Therefore, it makes sense to target insecticide treatment to this area, which is why **tray drench applications that soak this area are the most effective**, followed by transplant water applications. **Directed sprays in a narrow band at the base of the plant that use high water volume are more effective than wider bands** or DS applications made with lower water volumes, which are all more effective than broadcast sprays. **Higher rates and multiple applications are more effective than lower rates and single applications.**

Protection Against Cabbage Maggot Most Critical from April through June

CM flies begin to emerge from overwintering pupa in the soil in mid-April in New York, and continue to emerge for about 6 weeks until the end of May. The peak of spring emergence occurs in early May and coincides with full bloom of yellow rocket (*Barbarea vulgaris*). The flies mate and lay their eggs at the soil line at the stem of brassica seedlings. The eggs hatch within 3 days and maggots feed on the brassica stems for about 3 weeks before they pupate. First-generation CM flies emerge from pupae 2-4 weeks later beginning in late-May through the end of June with the peak flight occurring in mid-June, which coincides with full bloom of orange day lily (*Hemerocallis fulva*). **Although there are two more CM generations, they are much less favored by hot and dry summer conditions, and larger plants (stem diameter > pencil-sized) are much more tolerant to CM.**

It is recommended to consider applying protection beginning one week after initial fly emergence and continued until at least a week after peak flight activity, a total period of 2-4 weeks. You can track CM emergence in your area using NEWA and by paying attention to bloom of yellow rocket and orange day lily for overwintering and first CM generations, respectively. **Treatments applied at- or closely following planting can be augmented with additional DS applications of Mustang Maxx, Radiant, Coragen or Verimark to target peak emergence or extend residual control.**

Table 1. Roster of Insecticides Labeled in New York for Cabbage Maggot Control in Brassicas, 2022.

Product	Active Ingredient	IRAC[1] Group	Rate	Application Method[2]	Crops Labeled	Relative Control of Cabbage Maggot[3]	Other Insect Pests Controlled[4]	PROS	CONS
Diazinon AG500, 50W, AG600 WBC	diazinon	**1B**	2-3 qt/A, 4-8 fl oz/50 gal TW (AG500)	PPI, TW	broccoli, Brussels sprouts, cabbage, cauliflower / broccoflower and rutabagas (PPI only).	**TW: Excellent PPI: Poor**	Cutworms, wireworms	Long residual control	High risk for worker exposure – extensive PPE required[5]. Federally-restricted use[6]. TW application can cause significant stunting[7].
Mustang Maxx	zeta-cypermethrin	**3A**	3.2-4 fl oz/A	DS	Radish, rutabaga, turnips[8]	**4 apps – Good**	Worms, thrips, FB	Affordable (~ $16/A for 4 x 4 fl oz) Section 2(ee) label expansion for head & stem brassicas has been requested in NY.	Multiple applications required for effective control (short residual).
Capture LRF, Sniper LFR, Ruckus LFR	bifenthrin	**3A**	3.4-6.8 fl oz/A	IF, PRE, PPI	Head & Stem brassicas only	**Failed** in Cornell trials	Worms, thrips, FB	---	Coverage is critical, a.i. binds tightly to soil and organic matter.
Radiant SC	spinetoram	**5**	5-10 fl oz	DS 100 gpa	Head & Stem brassicas only	**Moderate** (labeled as suppression only)	Worms, thrips	---	---
Coragen	chloran-traniliprolie	**28**	3.5-7.5 fl oz	TW, IF, DS	Head & Stem brassicas only	**Poor-Moderate** (labeled as suppression only)	Worms	Affordable (~ $11/A (5 fl oz)) Minimum PPE requirements.	---
Verimark	cyan-traniliprole	**28**	10-13.5 fl oz/A	TD, TW, IF, DS	ALL	**TD: Good DS: Moderate**	Worms, FB	Excellent control of worms and FB. Minimal PPE required.	Tray drench application tricky. Expensive, but control of other insects could offset price. Plants must be planted within 72 h of treatment. Rate per plant can vary widely depending on planting density.

1 **IRAC**: **Insecticide Resistance Action Committee**. Active ingredients within an IRAC group have the same mode of action and cross-resistance may occur among them. Rotation among IRAC groups for resistance management is recommended.

2 **Application Method: PP**I: surface broadcast spray that is incorporated 3-4 inches pre-plant. **TW**: transplant water treatment. **DS**: directed spray at base of plant in 4-6 inch band, post-planting. **IF**: in-furrow at-planting application. **PRE**: applied with pre-emergent herbicides, broadcast surface application, not incorporated. **TD**: plug transplant tray drench.

3 Relative control ratings are based mostly on Cornell trials conducted by Zaman 2018-2021, and Hoepting & Nault, 2021.

4 **Worm** pests such as diamondback moth, imported cabbage worm, etc. **FB**: flea beetles.

5 PPE required for Diazinon includes a respirator with organic vapor cartridges, chemical resistant footware, chemical resistant gloves made of barrier laminate or viton, and goggles/face shield.

6 In NY, Federally-Restricted Use pesticides require that the applicator, which in the case of transplanting brassicas, would be the operator of the tractor pulling the transplanter, have their pesticide spray license or be supervised on-site within voice contact by a certified pesticide applicator.

7 Diazinon AG500 3 qt/A TW resulted in 46% stunting 25 days after planting in the on-farm trial in Oakfield (Hoepting & Nault, 2021). The label also cautions that TW application may cause stunting. Although the plants eventually grew out of the stunting, it seems backwards to apply a treatment that may cause stunting in order to protect the crop from an insect that can cause stunting.

8 **Mustang Maxx** is labeled on head and stem brassicas for other insect pests including worms, thrips and flea beetles. It is hoped that there will be a Section 2(ee) label expansion to include cabbage maggot on head & stem brassicas for Mustang Maxx and Hero (zeta-cypermethrin + bifenthrin) in time for the 2022 growing season.

Table 2. Evaluation of Select Insecticides for Control of Cabbage Maggot in Cabbage (c.v. Bravo) in Riverhead, NY (Long Island) in 2020 and 2021 (Zaman).

Year	Treatment, Rate and Application Type[1]	% Cabbage Maggot Infested Plants (/20 plants/plot)	Mean Cabbage Maggot Damage Severity Rating (Scale 0-10)[2]
2020	Nontreated Control	91.3 a[3]	3.26 a
	Lorsban 75WG 1.8 oz/1000 row feet	32.5 b (=64% control)	0.61 b (=81% control)
	Verimark 13.5 fl oz/A TD (= 0.0008 fl oz/plant) Fb. **Verimark 13.5 fl oz/A DS 64 gpa – 14 days**	41.2 b (=55% control)	0.84 b (=74% control)
	Radiant SC 10 fl oz/A DS 64 gpa	56.2 b (= 38% control)	1.22 b (=63% control)
	p value (α = 0.05)	*0.0012*	*0.0002*
2021	Nontreated Control	57.5 a	1.15 a
	Verimark 13.5 fl oz/A TD (= 0.0008 fl oz/plant)	25.0 b (= 56% control)	0.46 b (= 60% control)
	Mustang Maxx 4 fl oz/A DS x4 64 gpa	15.8 b (= 72% control)	0.21 b (=82% control)

1 **TD**: tray drench, applied with 1 pt of water over top of foliage, then "watered" in with another 1 pt of water per 200-cell tray. **DS**: directed spray at the base of the plant at-planting and again 3 more times every 7 days.

2 **Cabbage Maggot Damage Severity Rating Scale, 0-10**: 0 = no damage; 1-3 = minor damage that is not expected to affect yield; 4-7 = moderate damage that may affect yield slightly; 8-10 = severe damage that is expected to reduce yield

3 Numbers in a column followed by the same letter are not significantly different, Tukey's HSD test, p>0.05

Table 3. Evaluation of Insecticides for Control of Cabbage Maggot in Cabbage (c.v. Speedway Conqueror), Oakfield, NY, 2021 (Hoepting & Nault). Funding provided by Ny Cabbage Research and Development Program (CRDP).

Treatment			June 10, 11, 16 (40-46 DAT)	
No.	Product and Rate/A	Application Method (at-planting)[1]	% Cabbage Maggot Infested Plants (/20 plants/plot)[2]	% Plants Infested with Cabbage Maggot that are Stunted[3]
1	Nontreated	N/A	51.5 ab[4]	6.7
2	**Lorsban 4E 4.5 pt** (= 4.65 fl oz/1000 row feet)	DS 40 gpa	26.6 bc	8.3
3	**Diazinon AG500 3 qt**	PPI 3-4" depth	43.2 ab	4.5
4	**Diazinon AG500 3 qt**	TW 600 gpa	3.8 c[5] (=93% control)	0.0
5	**Verimark 6.5 fl oz**	DS 40 gpa	60.0 a	10.0
6	**Verimark 13.5 fl oz**	DS 40 gpa	34.1 ab	5.0
7	**Verimark 6.5 fl oz** (= 0.0004 fl oz/plant)	TW 600 gpa	45.3 ab	1.3
8	**Radiant SC 5 fl oz**	DS 100 gpa	25.3 bc	5.0
9	**Radiant SC 7.5 fl oz**	DS 100 gpa	40.4 ab	4.6
10	**Radiant SC 10 fl oz**	DS 100 gpa	34.6 ab	3.6
11	**Radiant SC 5 fl oz** Fb. **Radiant SC 5 fl oz** 18 DAP[6]	DS 100 gpa DS 100 gpa	33.7 ab	7.3
12	**Coragen 5 fl oz**	TW, 600 gpa	48.4 ab	8.0
	p value (α=0.5), Fisher's Protected LSD Test		*0.0249*	*NS*[7]

1 Treatments applied at-planting (PPI & TW) or 4 days after planting (DS), except 18 DAP2. **DS**: Directed spray at base of plant in 4-6 inch band. **PPI**: broadcast surface spray pre-plant incorporated. **TW**: Transplant water treatment.

2 All plants per plot that were stunted were selected to examine for signs of CM feeding, maggots and pupa. Healthy plants were randomly selected to round out the total number of plants examined for CM to 20

3 There were no significant differences among treatments for number of stunted plants per plot. Both stunted and healthy plants had CM feeding damage and infestation

4 Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test, p>0.05.

5 Plants in this treatment exhibited 46% stunting 25 days after planting, although by mid-June, they had recovered. The label states that TW application may cause stunting.

6 **DAP**: days after planting.

7 **NS**: Not significant, Fisher's Protected LSD test, p>0.05.

Table 4. Comparison of Directed Spray at Base of Plants After Planting (DS) to Tray Drench (TD) Applications of Radiant and Verimark for Control of Cabbage Maggot in Broccoli (c.v. Hercules), Gonzales, CA (Joseph & Iudice, 2013).

Treatment and Rate/A	Application Type[1]	% Cabbage Maggot Infested Plants	Notes
Nontreated Control	N/A	35 a[2]	---
Radiant SC 10 fl oz	**DS 2x**	18 ab	DS 2x damage as TD
	TD	10 b	= 71% control
Verimark 13.5 fl oz (= 0.0003 fl oz/plant)	**DS 2x**	15 ab	DS 3x damage as TD
	TD	5 b	= 86% control
	p value (α = 0.05)	*0.036*	---

1 **DS**: Directed spray at base of plant, 4" band, 2 and 16 days after planting. **TD**: Applied individually to each plug by using a syringe to inject treatment directly into soil media.

2 Numbers in a column followed by the same letter are not significantly different, Tukey's HSD test, p<0.05