ROOT MAGGOT CONTROL TRIAL

Root maggots (*Delia radicum*) represent a major problem for growers of cole crops in Saskatchewan. Maggots damage to the roots renders them less capable of delivering the water and nutrients required for optimal growth. In vegetable crops grown for their roots (rutabaga and radish), the scars left by the feeding maggots render the roots unmarketable. In Canada, the standard approach to controlling maggots is to apply the insecticide chlorpyrifos (Lorsban) as a root drench on several occasions through the growing season. The timing of chlorpyrifos application is targeted to correspond to the development of the maggot population. Applications of chlorpyrifos must cease 30 days prior to harvest for rutabaga. As organophosphates like chlorpyrifos are relatively toxic to both the applicator and the environment this type of pesticide has been targeted for phase out as soon as effective reduced-risk alternatives are identified.

The objectives of this project were to;

a) test new reduced-risk insecticides for potential use in root maggot management
b) look for alternatives to insecticides as a means to control root maggots

The insecticide testing project was conducted in 2009 and 2010 at the U of S Vegetable Crops Research Station in Saskatoon. Because of heavy root maggot pressure, production of vegetable cole crops is difficult at this site – even with repeated applications of pesticides.

Each treatment consisted of two adjacent rows of rutabaga (cv. Laurentian) spaced 60 cm apart, with each treatment replicated four times in a randomized complete block design. The plants were hand thinned to a 10 cm spacing soon after emergence. The plot was kept weed free by hand weeding. Overhead irrigation was used to maintain optimum soil moisture levels throughout the growing season. No problems with crop development or health were observed, beyond the expected problems with root maggots. Cool growing conditions in both years were favorable for rutabagas.

The root maggot control treatments tested in 2009 and 2010 are outlined in Table 1. Except for Trmt 1, the control products were applied three times over the season, starting at the first true leaf stage and then repeated at two week intervals (late June, mid-July and late July). In all cases except Trmt 9 the control products were applied using 80-08 flood nozzles to deliver the product in the equivalent of 1000 L/ha of water over a 15cm wide spray band. Trmt 9 was applied to the foliage in 100 L/ha of water using 8002 flat fan spray nozzles. Trmt 10 involved application of just water and served as the control. **Only Trmt 6 (chlorpyrifos) is presently registered for root maggot control on rutabaga in Canada.**

The efficacy of each round of spraying was evaluated 2 weeks after treatment. For the first 3 rating dates 10 plants from each treatment replicate were evaluated for root damage using a semi-quantitative 0-5 rating scale (0=no damage : 5=severe damage). A 0-4 damage scale was used for evaluations made at the final harvest. This method of evaluation is based on the number of knife cuts required to remove the maggot damaged tissues from mature roots (maximum of 4). Roots requiring 2 or fewer cuts to remove the maggot damaged tissues were considered marketable.

Results

Root maggot damage was more severe in 2009 than in 2010. In 2009 none of the roots in the untreated controls were marketable by the end of the growing season (Table 1), but in 2010 about 1/3 of the roots in the untreated control treatments were still marketable (Table 2). In both years maggot damage to the roots increased as the season progressed. The chlorpyrifos treatment provided a significant degree of maggot control in both years, resulting in a relatively high proportion of the crop meeting grade standards at the final harvest. The only other treatment that provided any consistent degree of control was the high rate of the presently unregistered product CCCCC**.**

Table 1. Influence of pesticides on root maggot damage rates in rutabaga (Saskatchewan 2009).

Treatment	Application	Maggot Damage Ratings				
		Jul-08[1)]	Jul-23	Aug-07	Aug-25[2)]	% marketable[3)]
1. AAAAAA	1 X Root drench	0.80	2.65	3.30	3.60	0
2. AAAAAA	3 X Root drench	0.80	2.10	2.80	3.25	0
3. BBBBBB	3 X Root drench	0.70	2.30	3.30	3.75	0
4. CCCCC (rate 1)	3 X Root drench	0.50	2.10	3.30	3.15	10
5. CCCCC (rate 2)	3 X Root drench	0.55	1.5	2.85	2.50	20
6. Chlorpyrifos	3 X Root drench	**0.05**	**0.25**	**0.75**	**0.85**	**75**
7. EEEEE	3 X Root drench	0.20	3.25	3.35	3.40	0
8. FFFFF	3 X Root drench	1.05	2.60	3.25	3.25	0
9. GGGGG	3 X Foliar	1.20	2.75	3.05	3.95	0
10. Water (control)	3 X Root drench	**1.10**	**3.25**	**3.45**	**3.85**	**0**

1. For Jul 8, Jul 23 and Aug 7 … a damage rating of 0=no damage : 5 = severe damage.
2. For Aug 25 … a damage rating of 0 = no damage : 1 = damage removed with one cut, 2 = two cuts, 4 = maximum.
3. Roots with a damage rating of 2 or less were considered to be marketable.

Table 2. Influence of pesticides on root maggot damage rates in rutabaga (Saskatchewan 2010).

Treatment	Rate[1]	Root maggot damage rating					
		Jul-07[1)]	Jul-23	Aug-06	Aug-26	Oct 6[2)]	% marketable[3)]
1. AAAAAA	1 X Root drench	0.45	1.25	2.40	1.85	1.85	75
2. AAAAAA	3 X Root drench	0.55	1.50	1.35	1.30	1.10	95
3. BBBBBB	3 X Root drench	2.05	1.95	2.50	1.90	1.80	75
4. CCCCC (rate 1)	3 X Root drench	1.15	1.45	1.55	2.0	1.30	78
5. CCCCC (rate 2)	**3 X Root drench**	**1.15**	**0.85**	**1.25**	**0.65**	**0.50**	**98**
6. Chlorpyrifos	**3 X Root drench**	**0.15**	**0.25**	**1.30**	**1.15**	**0.93**	**93**
7. EEEEE	3 X Root drench	2.0	2.50	3.1	2.85	2.60	50
8. FFFFF	3 X Root drench	1.05	2.05	2.3	3.0	2.28	63
9. GGGGG	3 X Foliar	1.70	2.70	3.1	3.25	2.38	55
10. Water (control)	3 X Root drench	**1.20**	**2.70**	**2.65**	**3.60**	**2.88**	**38**

1 For Jul 7, Jul 23, Aug 6 and Aug 26 … a damage rating of 0=no damage : 5 = severe damage.
2 For Oct 6 … a damage rating of 0 = no damage : 1 = damage removed with one cut, 2 = two cuts, 4 = maximum.
3 Roots with a damage rating of 2 or less were considered to be marketable.

This trial illustrates the severity of the maggot problem facing growers in Saskatchewan. Chlorpyrifos, which presently represents the standard treatment for maggots across Canada, provided a high level of maggot control in both years. While several of the new unregistered reduced risk insecticides provided an acceptable degree of protection when pest pressure was relatively light they did not provide sufficient protection when pest pressure was high. This suggests that while these new products may be useful as part of a maggot management program there is still needs to rely on Chlorpyrifos.

Root Maggot Interference Trials

Alternative (non-chemical) methods of root maggot management are clearly desirable – especially as the most effective chemical control product (Lorsban) is under regulatory review. One possible alternative approach to maggot control is to physically restrict the pests' access to the crop. Potential options for interfering with access to the crop include;

a) covering the crop with a semi-transparent field cover. Field covers are already extensively used in production of high value vegetable crops – primarily because the covers produce a warm, sheltered growing environment. Field covers may also protect the crops against insect pests.

b) fencing. The adult root maggot fly is know to prefer to fly less than a meter above the ground when seeking egg laying sites at the base of its host plant. It is therefore possible to use relatively short fences to protect the crop – assuming that the fence is designed from material that is too finely woven to allow the root maggot flies access to the crop.

In 2010 we assessed field covers and fencing as a means of protecting a rutabaga crop. The trial was conducted utilizing the production practices previously outlined. Each treatment consisted of 15 rows (8 m long) with a single plot for each treatment. As soon as the crop was seeded the "interference" treatments were put into place. The field cover was Agryl P-17 (1.7 oz/m2). This material is thin and light weight, allowing about 80% of the sunlight to pass. The mesh for the woven polyester is far too small to allow passage by root maggot flies. The entire plot was covered with a single sheet of the cover, with the edges sealed with soil. The covers were only removed briefly to allow for thinning, weeding, and crop evaluation.

The maggot fence was constructed by sandwiching a sheet of finely woven row cover (Agryl P-17) between two layers of standard plastic snow fence. The fence stood about 1.3 m in height and was supported at the corners by angle iron fence posts.

While the field covers and fences may be effective at preventing access to the crop by passing maggot flies, they cannot protect the crop against any flies that may emerge from pupae that overwintered within the protected area. For that reason half of each plot was treated at regular intervals with the standard insecticide (Lorsban).

A late planted crop was also tested to determine if it might be possible to reduce crop damage by avoiding at least some of the peak egg period. In previous trials we had found that egg laying commenced in late May and peaked in mid-late June. The late planted crop was therefore planted in mid-June so it would emerge after the peak of egg laying.

Maggot damage was assessed at intervals over the course of the 2010 growing season using the previously described damage rating system. A standard non-protected plot was used in all comparisons. The plot was harvested once the crop matured (Oct. 6) at which time the weight and degree of root maggot damage was evaluated. At the final harvest the degree of root maggot damage was evaluated based on the number of cuts required to remove visible maggot damage from the roots.

Results

Crop growth - within 3 weeks of crop emerge it became clear that both the field cover and fencing treatments were enhancing crop growth relative to the non-covered treatments - this beneficial effect persisted through the growing season for the fenced trial. It seems likely that the crop covers and fences were protecting the crop from wind damage.

By mid-summer more leaf disease (Cercospora sp) was present in the covered crop than for any of the other treatments. This disease did not appear to progress much over the course of the growing season and was unlikely to have affected yields. However by mid-summer the covered crop began to take on an abnormally "leggy" appearance – the tops were taller and thinner than normal and development (swelling) of the tap root appeared to stall.

Heavy rainfall interfered with pre-plant tillage operations for the late planted crop and the crop was seeded into sub-optimal soil conditions. This resulted in an inferior stand relative to the early planted crop. Otherwise, the late planted crop appeared to do well.

Treatment management – the field cover was easy to install and maintain. The cover stayed in place through several storm events and was easily repositioned if it did blow loose. The fencing required much more work to install and maintain. The fence tended to blow down during storm events despite efforts to

re-enforce the supporting posts. The fence also interfered with the machinery used in crop maintenance – by contrast the field covers were easily removed and replaced once tillage or spraying was completed.

Maggot control – root maggot damage to the roots increased in all treatments as the season passed. The field cover and to a lesser extent the fence provided some degree of maggot protection over the duration of the growing season (Table 3). Combining the field cover or fencing treatments with Lorsban treatments provided a high level of crop protection but it is unlikely that the observed additional degree of protection achieved with the cover or fence would have warranted the associated costs of materials and labor required to construct and maintain these crop protection systems.

Delaying planting by three weeks did not appear to mitigate the maggot pressure (Table 3) – perhaps an even later planting date is required in order to avoid the first egg laying generation but this will necessarily delay crop development – leading to a loss in yields and also increasing the risk of damage to the crop by the larger 2nd generation of maggot flies that emerges in late summer.

Yields – root yields prior to grade out due to maggot damage were increased by the Lorsban treatments (Table 3). This would be expected if the Lorsban treatments had protected the feeder roots from damage by the maggots. Average size of the roots was larger in the fenced treatments than for other treatments planted at a comparable time. We had noted that the fencing treatments appeared to be enhancing crop growth. The average root size for the late planted crop was also large – but this likely reflects the fact that the stand for this crop was quite thin – so each plant was provided with more abundant growing space than for the earlier planted crops. The Lorsban treatments substantially reduced the amount of root maggot damage at the final harvest and this resulted in a substantial increase in the proportion of the crop that would have met grade standards for freedom from excessive maggot damage. None of the maggot interference treatments substantially increased the proportion of the crop that made grade standards – except that when Lorsban was not used, having the crop protected by a field cover did increase the proportion of roots that met grade tolerances for maggot damage (Table 3).

Table 3. Root maggot damage and root yield data for rutabaga over the course of the 2010 growing season as influenced by various crop protection systems, with or without supplemental application of Lorsban

	Avg Damage Rating (July-Aug) [1]			**Yield (kg/plot)**			**Final Damage Rating (Oct 6)** [2]			**% Marketable** [3]		
	Lorsban		**Avg**	**Lorsban**		**Avg**	**Lorsban**		**Avg**	**Lorsban**		**Avg**
	+	-		+	-		+	-		+	-	
Control	1.0	2.8	**1.9**	5.2	3.8	**4.5**	1.7	2.9	**2.3**	83	29	**56**
Field Cover	0.4	1.5	**1.0**	5.6	3.8	**4.7**	1.6	1.9	**1.7**	83	62	**73**
Fenced	0.6	2.6	**1.6**	5.7	6.4	**6.0**	1.0	2.6	**1.8**	83	33	**58**
Late Planted	0.8	2.8	**1.8**	6.4	5.7	**6.0**	1.3	2.5	**1.9**	88	37	**63**
Avg	**0.7**	**2.4**		**5.7**	**4.9**		**1.4**	**2.5**		**84**	**40**	

[1] Root damage graded according to method of Dosdall et al; numbers represent means of four 10-plant samples
[2] Root damage rating based on number of cuts required to remove maggot damage (0 to maximum of 4)
[3] Roots considered marketable if maggot damage could be removed with a maximum of 2 cuts

While the use of crop covers or fencing to protect crops from maggot damage makes sense in principal – in practice neither technique provided any consistent or economically significant degree of protection. Both fencing and covers involved considerable additional costs and tended to interfere with other aspects of normal crop maintenance. The crop covers also appeared to compromise crop health late in the season.

Companion Cropping Trial

Companion cropping involves mixing two or more crop species within a field in an effort to enhance productivity – with the companion crops "helping" the other crop by repelling insect pests or by providing nutrients.

Root maggot flies seeking an appropriate site for egg laying identify suitable hosts by a combination of visual cues and odor. The presence of non-host plants in the immediate vicinity of the potential host tends to "confuse" the flies, reducing egg laying. The flies are attracted by the volatile sulphur-based compounds that give members of the Brassicacea their characteristic odor.

This study sought to determine whether root maggot damage to a high value vegetable crop (rutabaga) could be mitigated by inter-planting the rutabagas with either a non-host "companion" crop like wheat that would physically interfere with egg laying or a faster growing and stronger smelling (more attractive) brassica crop like oilseed mustard.

The trial was conducted at the University of Saskatchewan Vegetable Crops Research site in Saskatoon (see previous for site details). The rutabagas (cv. Laurentian) were planted in rows alternating with rows of;

a) rutabaga (standard)
b) oilseed mustard
c) wheat

The wheat and oilseed mustard companion crops were planted 1 week ahead of the rutabaga so that these companion plants would be larger than the rutabaga. It was anticipated that the efficacy of these treatments in either or confusing or diverting the maggot flies would be enhanced by increasing plant size.

Each plot row was 8 m long and each treatment was replicated four times in a randomized complete block design. The plot was kept weed free by hand weeding. Due to abundant rainfall in 2010 no supplemental irrigation was required.

One half of each treatment row of rutabaga (4m) was treated at regular intervals with Lorsban (see above for description of treatment method). This allowed for comparison of the companion treatments with and without supplemental control via insecticides.

At regular intervals over the growing season root samples (n=10) were evaluated for root maggot damage using the previously described rating system. The plot was harvested once the crop matured (Oct. 6) at which time the weight and degree of root maggot damage was evaluated for 20 randomly selected roots from each treatment replicate. At the final harvest the degree of root maggot damage was evaluated based on the number of cuts required to remove visible maggot damage from the roots (0 to a maximum of 4). Roots requiring 2 or less cuts were considered to be marketable.

Results

Crop growth - both the oilseed mustard and wheat established quickly and, as designed, were well advanced prior to the emergence of the rutabaga. Both of the "companion" crops grew more quickly than the rutabaga – this resulted in considerable shading of the rutabaga crop – especially by the sprawling oilseed mustard plants. To reduce this competition, both companion crops were "topped" to the height of the adjacent rutabaga plants in mid-July and again in mid-August. Despite this effort to control competition by the companion plants, the root size of the rutabaga plants growing next to the oilseed mustard plants were smaller than normal, with the largest roots occurring when rutabaga was grown adjacent to other rows of rutabaga (Table 4).

Maggot control – the extent of maggot damage to the roots increased as the season progressed, except towards the end of the season, when the roots grew more rapidly than the maggot damage.
Neither of the companion crops had any significant impact on the intensity of root maggot damage to the rutabaga crop at any of the early sampling dates (Table 4) As seen in the other experiments, the multiple

Lorsban treatments again provided a significant degree of maggot protection throughout the growing season.

Yields – both companion crops reduced yields of the adjacent rutabaga plants (Table 4). This occurred despite the fact that the companion plants were pruned back to the height of the adjacent rutabagas on two occasions during the growing season. Competition is one of the major limitations of using companion planting to limit pests in relatively non-competitive horticultural crops. While the damage rating taken early in the growing season had shown little consistent benefit of the companion plantings, at the final harvest having mustard as a companion plant significantly reduced root maggot damage to the adjacent rows of rutabaga. The degree of root maggot protection was equivalent to the degree of benefit achieved with multiple applications of Lorsban. When considering the proportion of the crop that would have been considered to be marketable based on freedom from excess root maggot damage (damage rating <2.0), the combination of Lorsban+mustard as a companion crop was clearly superior (78% marketable), while rutabaga grown without either insecticide or a companion crop had the highest rate of grade-out due to excessive maggot damage (23% marketable).

Table 4. Root weights, root damage ratings and % marketable roots as influenced by various companion crops with or without supplemental application of Lorsban

	Avg Damage Rating (July-Aug) [1]			Yield (kg/plot)			Final Damage Rating (Oct 6) [2]			% Marketable [3]		
	Lorsban			Lorsban			Lorsban			Lorsban		
Companion Crop	+	-	Avg	+	-	Avg	+	-	Avg	+	-	Avg
Mustard	0.6	2.3	1.5	4.1	5.1	4.9	1.6	2.1	1.8	78	50	64
Wheat	0.7	2.9	1.8	5.5	4.8	5.1	2.3	2.6	2.5	45	52	48
Rutabaga	0.7	2.7	1.7	9.2	6.4	7.8	2.2	3.2	2.7	58	23	40
Avg	0.7	2.6		6.2	5.4		2.0	2.6		60	41	

[1] Root damage graded according to method of Dosdall et al; numbers represent means of four 10-plant samples
[2] Root damage rating based on number of cuts required to remove maggot damage (0 to maximum of 4)
[3] Roots considered marketable if maggot damage can be removed with a maximum of 2 cuts

Establishing and maintaining the companion crops required some additional effort. The yield data suggests that the companion plants need to be managed in a manner that more effectively limited their ability to compete with the rutabaga crop (ie; more frequent/aggressive pruning). This management would need to be achieved without compromising the value of these crops as means of protecting the target crop from insect damage. Another possibility would be to select companion plants with a less aggressive growth habit (ie; kale as a mustard crop and spring planted winter wheat as a cereal). However it is thought that larger plants are more effective as an attractant/distraction or more effective as a screen – therefore a less vigorous companion crop may be undesirable. While the companion crops appeared to have little consistent beneficial effect on root maggot damage ratings taken over the duration of the growing season, by the final harvest having mustard as a companion significantly reduced the severity of maggot damage and increased the proportion of the crop that would have made grade standards for freedom from excessive maggot damage. The validity/basis of this apparent anomaly needs to be explored by further testing. It is noteworthy that the increase in marketable % achieved using mustard as a companion plant almost exactly offset the loss in total yield caused by competition between the rutabaga crop and the companion mustard planting.

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