ROOT MAGGOT CONTROL TRIAL

Root maggots (*Delia radicum*) represent a major problem for growers of vegetable cole crops in Saskatchewan. Maggots damage to the roots renders them less capable of delivering the water and nutrients required for optimal growth. In crops grown for their roots (rutabaga and radish), the scars left by the feeding maggots will render the roots unmarketable. Presently 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(s) is targeted to correspond to the development of the maggot population. Application of chlorpyrifos must cease 30 days prior to harvest for rutabaga. Organophosphates like chlorpyrifos have 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 means to control root maggots

Insecticide Testing

An insecticide testing project was conducted in 2009-2012 at the U of S Vegetable Crops Research Station in Saskatoon. Because of heavy root maggot pressure at this site, production of vegetable cole crops is difficult – even with repeated applications of pesticides.

Each insecticide 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 rutabaga seedlings were hand thinned to 10 cm apart soon after emergence. The plot was kept weed free using herbicides and 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. Growing conditions in all four years were favorable for rutabagas.

The insecticide treatments tested 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 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 7 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 the insecticides was evaluated at several points over the growing season (data not shown) and again at the final harvest. Roots requiring 2 or fewer cuts to remove the maggot damaged tissues were considered marketable.

Results

Root maggot damage was less severe in 2010 and 2012 than in 2009 or 2011. In 2009 and 2011 none of the roots in the untreated controls were marketable by the end of the growing season (Table 1). In all years maggot damage to the roots increased as the season progressed. The chlorpyrifos treatment provided effective maggot control in all years, resulting in a relatively high proportion of the crop meeting grade standards at the final harvest. The presently unregistered product CCCCC also provided a fairly consistent degree of root maggot control. Access to effective alternatives to chlorpyrifos (Lorsban) is highly desirable – especially as repeated applications of a single product exert significant selection pressure for pesticide resistance.

Table 1. Influence of pesticides on % marketable rutabaga.

Treatment	Application	2009)	2010	2011	2012	Average
1. AAAAA	1 X Root drench	0	75	4	51	32
2. AAAAA	3 X Root drench	0	95	50	81	57
3. BBBBB	3 X Root drench	0	75	26	83	46
4. CCCCC (rate 1)	3 X Root drench	10	78	52	88	65
5. CCCCC (rate 2)	3 X Root drench	20	98	86	96	75
6. Chlorpyrifos	3 X Root drench	**75**	**93**	**48**	**98**	**79**
7. Water (control)	3 X Root drench	**0**	**38**	**4**	**66**	**27**

Roots considered marketable if maggot damage can be removed with a maximum of 2 cuts

Root Maggot Interference Trials

While there are chemical control products that provide at least some degree of protection against root maggots, alternative methods of management are clearly desirable – especially as the only chemical control product that provides effective root maggot control (chlorpyrifos or Lorsban) is under regulatory review.

One possible alternative approach to maggot control is to physically restrict the pest's access to the crop. Potential options for interfering with access to the crop include;

a) covering the crop. Transparent field covers are already extensively used in production of high value vegetable crops, primarily because the covers produce a warm, sheltered growing environment conducive to faster growth and enhanced yields. However, field covers may also be used to protect crops against insect pests.

b) fencing. The adult root maggot fly tends to stay less than a meter above the ground when seeking its preferred egg laying sites at the base of the 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 fly access to the crop.

In 2010, 2011 and 2012 we assessed field covers and fencing as a means of protecting a rutabaga crop from root maggot damage.

The trials were conducted at the University of Saskatchewan Vegetable Research plots in Saskatoon. All production practices were as previously outlined. Each treatment consisted of 15 rows (8 m long) of rutabaga (cv. Laurentian) spaced 0.6 m apart, with a single plot for each treatment. As soon as the crop was seeded the "interference" treatments were put into place.

In 2010 Agryl P-17 (1.7 oz/m2) was used as a field cover. This material is thin and light weight, allowing about 80% of sunlight to pass. The mesh for the woven polyester is far too small to allow passage by root maggot flies, but is hopefully sufficiently airy to prevent overheating of the crop. 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. In the 2011 and 2012 trials, P-17 was tested again, along with a specifically designed insect cover. This insect material has a more open mesh – (20/inch) although the holes are still too small to allow passage of the root maggot fly.

In the 2010 trial a "maggot fence" was constructed by tacking a sheet of finely woven row cover (Agryl P-17) to a standard plastic snow fence. The fence stood about 1.3 m in high. In 2011 and 2012 we tested a custom manufactured "maggot fencing" system designed by scientists at AAFC Agassiz, B.C. The unique aspect of this custom fence is that the mesh material forms a crook at the top of the fence – this feature is designed to deflect downward any flies encountering the fence.

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 have overwintered within the protected crop area. For that reason half of each plot was treated at regular intervals with the insecticide chlorpyrifos (Lorsban), as this product has provided effective root maggot control in other trials.

Standard crop maintenance procedures were employed in all years. The plot was harvested once the crop matured at which time the weight and degree of root maggot damage was evaluated for 20 randomly selected roots from each treatment. Roots were considered marketable if all maggot damage could be removed with two or less cuts. A standard non-protected plot was included in all comparisons.

Results

Crop growth – in all years, the field cover and fencing treatments enhanced early growth relative to the non-covered treatments. While it was not possible to determine the exact cause of this beneficial effect, it seems likely that the crop covers and fences were protecting the emerging seedlings from wind damage. The crop covers may also have been increasing air temperatures in the crop canopy – which may have been beneficial early in the season.

By mid-summer the crop covered with the P-17 material began to take on an abnormally “leggy” appearance – the tops were taller and thinner than normal. At the same time development (swelling) of the tap root appeared to stall. This growth effect was not observed when the crop was covered with the better ventilated insect cover.

Treatment management – the field covers were relatively easy to install and maintain. They stayed in place through several severe storm events and were easily repositioned if they did blow loose. Late in the growing season the growing crop began to push upwards against the covers and this tended to dislodge the covers more frequently. The maggot fence systems required more effort to install and maintain. The fences interfered with all forms of machinery used in crop maintenance – by contrast the field covers were easily removed and replaced once tillage or spraying was completed.

Yields – in all three years root weights were increased by the chlorpyrifos treatments (Tables 2, 3 and 4). This would be expected if the chlorpyrifos treatments had protected the feeder roots from damage by the maggots. The cover treatments increased total root yields relative to the control treatments in 2010 and 2011 but not in 2012. The fencing treatments did not enhance yields in any year. In all three years the Lorsban treatments substantially reduced the amount of root maggot damage seen in all treatments at the final harvest. This resulted in a substantial increase in the proportion of the crop that would have met grade standards for freedom from excessive maggot damage. If no insecticide was used, keeping the crop covered with the P-17 field cover increased the proportion of the 2010 crop that made grade tolerances for maggot damage. In 2011, the fencing treatment and the insect cover increased the marketable % for the crop in the absence of protectant insecticides. Fencing and both types of cover increased the marketable % in the 2012 trial.

Conclusion/Recommendations – three years of testing suggest that crop covers and fences do have the potential to provide at least some degree of crop protection against maggot damage. However both the crop covers and fences were expensive to install and required considerable maintenance. They also interfered with other aspects of normal crop maintenance. By comparison, application of the standard insecticide chlorpyrifos provided more effective crop protect than either the covers or fences, and at a fraction of the cost.

Table 2. Root weights, root damage ratings and % marketable roots as influenced by various protection systems, with or without supplemental application of the insecticide Lorsban – 2010 trial.

	Root weight (kg) [Z]		Damage rating [Y]		% marketable		Marketable Weight (kg)	
	Lorsban		Lorsban		Lorsban		Lorsban	
	+	-	+	-	+	-	+	-
No cover	5.2	3.8	1.7±0.26	2.9±0.26	83	29	4.3	1.1
P-17	5.6	3.8	1.6±0.31	1.9±0.40	83	62	4.6	2.4
Fenced	5.7	6.4	1.0±0.31	2.6±0.40	83	33	4.7	2.1
Avg	**5.5**	**4.7**	**1.4**	**2.5**	**83**	**41**	**4.5**	**1.9**

[Z] Weight of 20 randomly selected roots.

[Y] Damage rating based on number of cuts required to remove maggot damage (0 to maximum of 4). Mean±SE.

Roots considered marketable if maggot damage can be removed with a maximum of 2 cuts

Table 3. Root weights, root damage ratings and % marketable roots as influenced by various protection systems, with or without supplemental application of the insecticide Lorsban – 2011 trial.

	Root weight (kg/plot)		Damage rating [Z]		% marketable		Marketable Weight	
	Lorsban		Lorsban		Lorsban		Lorsban	
	+	-	+	-	+	-	+	-
No cover	20.8	17.4	2.4±0.15	3.6±0.31	45	20	9.4	3.5
P-17 cover	28.3	22.1	1.0±0.22	3.3±0.27	100	15	28.3	3.3
Anti-insect cover	28.2	15.2	0.8±0.31	1.7±0.45	95	65	26.7	9.9
Fenced	17.4	17.5	2.2±0.22	2.6±0.36	60	50	10.5	8.7
Avg	**23.7**	**18.0**	**1.6**	**2.8**	**75**	**38**	**18.8**	**6.4**

[Z] Damage rating based on number of cuts required to remove maggot damage (0 to maximum of 4). Mean±SE.

Roots considered marketable if maggot damage can be removed with a maximum of 2 cuts

Table 4. Root weights, root damage ratings and % marketable roots as influenced by various protection systems, with or without supplemental application of the insecticide Lorsban – 2012 trial.

	Root weight (kg/plot)		Damage rating [Z]		% marketable		Marketable Weight	
	Lorsban		Lorsban		Lorsban		Lorsban	
	+	-	+	-	+	-	+	-
No cover	12.4	9.8	0.2±0.10	1.6±0.22	100	64	12.4	6.3
P-17 cover	6.9	7.7	0	0.2±0.11	100	100	6.9	7.7
Anti-insect cover	11.5	9.0	0	0.6±0.24	100	92	11.5	8.3
Fenced	10.8	11.0	0	0.2±0.12	100	100	10.8	11.0
Avg	**10.4**	**9.4**	**0.1**	**0.6**	**100**	**89**	**10.4**	**8.3**

[Z] Damage rating based on number of cuts required to remove maggot damage (0 to maximum of 4). Mean±SE.

Roots considered marketable if maggot damage can be removed with a maximum of 2 cuts

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 identify suitable hosts for egg laying 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 during 2010, 2011 and 2012 (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 **d) no crop (2011 and 2012)**

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. To reduce competition with the rutabaga crop, both companion crops were "topped" to the height of the adjacent rutabaga plants in mid-July and again in mid-August.

Each plot row was 8 m long and each treatment was replicated four times in a randomized complete block design. One half of each treatment row of rutabaga (4m) was treated at regular intervals with chlorpyrifos (see above for description of treatment method). This allowed for comparison of the companion treatments with and without supplemental control via insecticides.

The trials was harvested once the crop matured, 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. 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. This competition occurred despite the companion crops being topped twice over the course of the growing season.

Yields and Maggot Control – in the 2010 trial the companion crops reduced yields of the adjacent rutabaga plants relative to when the adjacent plant was a rutabaga (Table 5). By contrast in the 2011 and 2012 trials, yields from the plots where the rutabaga crop was interplanted between rows of wheat or mustard were actually higher than when the adjacent row was also planted to rutabaga (Tables 6 and 7). In 2011 yields of all three interplanted rutabaga crops were less than 50% of the yields observed when the rutabaga test rows were flanked by blank, unplanted rows. In 2012 yields of the crop interplanted with mustard were equivalent to the yields obtained when the adjacent rows were not planted. It is noteworthy that in the 2012 trial, the mustard struggled to get established under the extremely wet conditions that prevailed through early summer. These results suggest that the rutabaga crop is experiencing competition pressure from adjacent rows of companion plants. This competition was greatest when the adjacent rows contained vigorous plants (untrimmed rutabaga) but was still significant when the companion plants (wheat or mustard) were pruned back to the height of the adjacent rutabagas on two occasions over the course of the growing season. Competition is one of the major limitations of using companion planting to limit pests in relatively non-competitive horticultural crops.

In the 2010 trial having mustard as a companion plant significantly reduced root maggot damage to the adjacent rows of rutabaga (Table 5). The degree of root maggot protection achieved by interplanting with mustard 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). The enhancement in marketable % achieved by interplanting the rutabaga crop with mustard was not sufficient to overcome the negative effect exerted on yields by competition from the mustard crop. As a consequence, the highest marketable yields in the 2010 trial were obtained when a less competitive rutabaga crop was grown in the adjacent rows. Averaged across interplanting treatments, application of the insecticide Lorsban to the 2010 crop increased the marketable % by 19% and marketable yields by 68%.

Table 5. Root weights, % marketable roots and marketable root weights as influenced by various companion crops with or without supplemental application of Lorsban – 2010 trial.

	Yield (kg/plot)			% Marketable			Marketable (kg/plot)		
	Lorsban			Lorsban			Lorsban		
Companion Crop	+	-	**Avg**	+	-	**Avg**	+	-	**Avg**
Mustard	4.1	5.1	**4.9**	78	50	**64**	3.2	2.6	**2.9**
Wheat	5.5	4.8	**5.1**	45	52	**48**	2.5	2.5	**2.5**
Rutabaga	9.2	6.4	**7.8**	58	23	**40**	5.3	1.5	**3.4**
Avg	**6.2**	**5.4**		**60**	**41**		**3.7**	**2.2**	

[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

Having mustard as the companion crop increased the proportion of roots that were sufficiently free of maggot damage to be considered "marketable" (damage rating <2.0) by 10% relative to the next best treatment – this was comparable to the average benefit achieved using multiple applications of Lorsban (11% increase in marketable roots)(Table 6). While having no companion crop had resulted in a high % grade out to maggot damage, the lack of competition from adjacent crop rows resulted in the few remaining marketable roots growing to exceptional size. As a consequence, the highest marketable yields in the 2011 trial were obtained when the rutabaga tests rows were flanked by blank rows (Table 6).

Table 6. Root weights, % marketable roots and marketable root yields as influenced by various companion crops with or without supplemental application of Lorsban – 2011 trial

	Yield (kg/plot)			% Marketable			Marketable (kg/plot)		
	Lorsban			Lorsban			Lorsban		
Companion Crop	+	-	**Avg**	+	-	**Avg**	+	-	**Avg**
Mustard	6.6	4.3	**5.3**	82	65	**74**	5.4	2.8	**4.1**
Wheat	4.3	5.8	**5.0**	40	43	**41**	1.7	2.5	**2.1**
Rutabaga	4.0	3.5	**3.7**	78	50	**64**	3.1	1.8	**2.5**
No Crop	**16.8**	**10.3**	**10.9**	**48**	**45**	**46**	**8.1**	**4.6**	**6.3**
Avg	**8.0**	**6.0**		**62**	**51**		4.6	2.9	

[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

In the 2012 trial root maggot damage ratings had been relatively low throughout the growing season. The 2012 crop was also harvested relatively early (Sept. 12). Both of these factors would have contributed to the relatively minor root maggot damage observed at the final harvest in 2012 (Table 7). None of the companion plants treatment had any significant impact on the degree of grade-out due to maggot damage at the final harvest in 2012. Once again, having mustard as the companion crops exerted the least drag on total yields, while having rutabagas growing in the adjacent rows appeared to exert the greatest competition effect. Although root maggot pressure was relatively light in 2012, it is noteworthy that treating with the insecticide Lorsban increased both the total yields and the yields of roots that met grade standards for freedom from excess maggot damage. A similar positive effect of the Lorsban treatments on total yields was also observed in the 2010 and 2011 trials. This suggests that by protecting the roots from maggot damage the Lorsban treatments were increasing total productivity – perhaps because the root maggots were damaging the feeder roots required for nutrient and moisture uptake.

Table 7. Root weights, % marketable roots and marketable root yields as influenced by various companion crops with or without supplemental application of Lorsban – 2012 trial

	Yield (kg/plot)			**% Marketable**			**Marketable (kg/plot)**		
	Lorsban			**Lorsban**			**Lorsban**		
Companion Crop	+	-	**Avg**	+	-	**Avg**	+	-	**Avg**
Mustard	9.0	9.6	**9.3**	100	87	**93**	9.0	6.3	**7.7**
Wheat	8.2	5.4	**6.8**	100	90	**95**	8.2	4.9	**6.6**
Rutabaga	4.1	3.4	**3.7**	100	83	**91**	4.1	2.8	**3.5**
No Crop	11.3	7.5	**9.4**	100	87	**93**	11.3	6.3	**8.8**
Avg	**8.1**	**6.5**		**100**	**87**		8.1	5.6	

[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

Conclusion/Recommendations – establishing and maintaining the companion crops required some additional effort. The yield data suggests that the companion plants needed to be managed in a manner that more effectively limited their ability to compete with the rutabaga crop (ie; wider row spacings, thinner planting density or 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 – for example kale is very attractive to root maggots and has a less aggressive growth habit than mustard. However it is thought that larger plants are more effective as an attractant/distraction – and therefore a less vigorous companion crop may be undesirable.

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