Evaluation of At-planting and Post-emergence Treatments for Control of the Sugarbeet Root Maggot *

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INTRODUCTION

The sugarbeet root maggot (SBRM), *Tetanops myopaeformis* (Roder), has one generation per year in western Canada and the population levels vary considerably from year to year. In years when populations are high, crop damage can be severe, resulting in large losses of yield (1,2,3,9,10,13). Effective control of the SBRM has been achieved with the application of an in-furrow granular insecticide during planting (2,3,10,13). Until recently, Furadan (carbofuran) 10G has been the preferred insecticide for use on sugarbeets in Canada because of its efficacy and relatively low phytotoxicity and cost (2,3). In the last few years, however, Furadan 10G applied to commercial sugarbeet fields has provided unsatisfactory control of the SBRM. Similar problems have been reported for control of the onion maggot, *Delia antiqua* (Meigen), with use of Furadan, ethion and Trithion (carbophenothion) (18). An effective alternative to the use of Furadan on sugarbeets is an in-furrow application of Temik (aldicarb) 10G. Treatment with this insecticide is more expensive than with Furadan and, based on reports from other areas, can present a potential problem for ground water contamination (7). Because of the sporadic nature of SBRM populations in southern Alberta, sugarbeet growers are advised to treat only when severe SBRM infestations are expected. Similar recommendations for insect control have been made elsewhere (6). Since there is no method for making an accurate prediction of an infestation by SBRM at planting time, and because crop loss from severe infestations in

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untreated fields can be great, growers have resorted to applying insecticides as insurance treatments. This practice is expensive and can lead to excessive and unwarranted pesticide use.

An alternative to application of insurance treatments is an effective control program that can be implemented after the sugarbeet plants and SBRM adults have emerged and the potential for infestation is known. Studies toward this goal have been conducted by several researchers with varying levels of success. Fumigating (12), applying an insecticide-impregnated pelleted seed (8), sidedressing an insecticide on the water side when early furrow-irrigation can be practised (4), top-banding after plant emergence and lightly raking in the insecticide (15,19), and spraying of foliar insecticides to kill the adult fly (5,14,16) have been investigated. Each of these methods of SBRM control has both beneficial and harmful attributes. Side-banding can physically damage the plants during application, and is restricted to growing areas where early season furrow-irrigation can be used to advantage. Top-banding after sugarbeet emergence is effective only if the insecticide is properly incorporated into the surface soil, but the required mechanical incorporation can damage the tender young plants. Control of adult flies, after they have emerged from the soil, is impractical. Assuming the insecticide reaches its target, the adults must be killed before they lay their eggs. Oviposition occurs within several days after adult emergence and emergence takes place over an extended period of time, thus necessitating repeated applications of insecticides (11,21).

The objective of this research was to develop a method for SBRM control that can be implemented after the sugarbeet plants and the SBRM have emerged and the potential for crop damage is known. In this paper we describe results from several experiments in which top-banded and post-emergence insecticide treatments incorporated with light sprinkler irrigation are compared with modififed in-furrow and at-planting press-wheel treatments. Almost all of the sugarbeets grown in southern Alberta are irrigated with overhead sprinklers.

METHODS AND MATERIALS

The 1983, 1984, and 1985 sites for evaluation of SBRM control were selected and prepared in the preceding fall adjacent to fields in Taber, Alberta, which had been severely infested by the SBRM in the preceding summer. Preparation of the plots included mold-board plowing, machine leveling, and application of a tank-mix of the herbicides Ro-Neet (cycloate) 72E and Nortron (ethofumesate) 18E in conjunction with fall ridging. The rates of herbicides used were appropriate for the particular soil type at each location. In the spring, plots were deridged in preparation for planting of sugarbeets. A precise soil guidance system was used in all field plot operations.

Products used in the experiments were: Broot (trimethicarb) 15G, Counter (terbufos) 15G, Dyfonate (fonofos) 10G, Dyfonate (fonofos) 40F, Furadan (carbofuran) 10G, Furadan (carbofuran) 48F, Lorsban (chlorpyrifos) 15G, Lorsban (chlorpyrifos) 40E, Oncol (benfuracarb) 10G, Oncol (benfuracarb) 30E, and Temik (aldicarb) 10G. In 1985, a new formulation of Lorsban 40E-HF (XRM-4764) expected to be marketed in 1986, was used in place of the commercially available formulation at the request of the manufacturer. Several check treatments were included in each experiment to allow destructive sampling during the growing season.

Sugarbeet seeds were planted 3.3 cm deep and 15 cm apart in rows spaced at 56 cm. The cultivar Primahill was planted in 1983 and 1985 and Salohill was planted in 1984. Individual plots consisted of 6 rows, 8 m in length, replicated 12 times in a randomized complete block design. Rows 1 and 6 did not receive experimental treatments but served as guard rows between plots and were treated with an in-furrow application of Temik 10G at 1.12 kg ai/ha at planting. Several methods of applying the insecticides were used. For in-furrow applications, granular insecticides were deposited behind the seed-furrow opener at the point where the furrow closed. This ensured that some soil fell onto the seed before the insecticide entered the furrow with the remaining soil and that a narrow band of treated soil was immediately above the seed, but not in direct contact with it. For press-wheel applications, insecticides were deposited directly into the narrow soil depression formed behind the single-rib press wheel. A light tine-rake was used to create a shallow mulched surface over the seed row and to cover the insecticide granules. Post-emergence treatments of granular and liquid insecticides were applied when SBRM adults had emerged and were active in the field. Adult emergence was monitored with emergence cages in nearby fields that had been planted to sugarbeets the previous year and by degree-day accumulation where 200 degree-days (base temperature of 8.6 C) is required for 50% SBRM adult emergence (20). Treatments were applied in a narrow band (10 cm wide) directly over the row. Granular treatments were applied with single-row cones that had been modified to ensure uniform metering. The liquid treatments were applied at 207 kPa in 224 L/ha (broadcast basis) of water with 8002E flat fan nozzles. All applications were made with tractor-mounted equipment.

All plots were sprinkler-irrigated for 2 hours immediately after application of post-emergence treatments to help move the insecticides into the soil layer where SBRM larvae were feeding. During the growing season, weeds were controlled with post-emergence applications of Poast (sethoxydim) 18EC, Betanal (phenmedipham) 15EC, and Betanex (desmedipham) 15EC. Plots were irrigated as required for good plant growth.

All treatments were rated for flea beetle, *Psylliodes punctulata* (Melsheimer) and *Phyllotuta cruciferae* (Goeze), damage by counting the number of "shot-holes" per leaf on 12 plants chosen at random in rows 3 and 4 of each plot. Plant stand was determined by counting all the plants in these same rows. Twelve beets selected at random from rows 2 and 5 were rated for damage by root maggots according to Yun (22) where: 0 = no scars, 1 = 1-4 small scars of pinhead size, 2 = 5-10 small scars, or up to 3 larger scars, 3 = more than 3 large scars, 4 = ½ to 3/4 of root area blackened, 5 = more than 3/4 of root area blackened, heavily damaged. At harvest all beets from rows 3 and 4 were mechanically defoliated and lifted. After being washed, the beet roots were weighed and a multi-saw rasp was used to obtain samples of brei for determination of percent sugar content.

The 1983 experiment was planted on 19 April but beets were killed by a sharp frost on 12-13 May. Seed was replanted on 14 May into exactly the same seed furrow, made possible by using the precise soil guidance system, and no insecticides were added with the replanted seed. On 7-8 June flea beetle damage was assessed. At the same time all beets in the center two rows of an untreated check (12 replications) were removed and examined for presence of root maggot damage. This information was used to verify SBRM activity in the field as predicted from emergence cages and degree-day monitoring. Post-emergence insecticides (listed in Table 1) were applied to untreated plots on 9 June. Plant stand was recorded on 7-8 June, 29 June, and 30 September. A second untreated check was removed on 29 June and beets were rated for SBRM damage. On 3 October all plots were harvested.

The 1984 experiment was planted on 1 May (treatments listed in Table 2). Flea beetle damage was evaluated on 30 May in the same manner described above. As in the previous experiment, one untreated check was removed on 4 June and the beets were examined for presence of root maggot damage. Post-emergence treatments were applied the same day at half the rate used in 1983. Plant stand was recorded on 30 May and 20 June. Root maggot damage was evaluated on 18-23 July, by selecting 10 beets at random from rows 2 and 5 of each plot. All plots were harvested on 3 October.

The 1985 experiment was planted on 21 May (treatments are listed in Table 3). Because of the late planting date, flea beetle density was low and damage was not recorded. Plant stand was recorded on 7 June, 22 July, and 26 September. On 2-3 July, 12 beets per plot were selected at random from rows 3 and 5 and rated for SBRM damage. All plots were harvested on 3 October.

RESULTS AND DISCUSSION

Feeding by adult flea beetles on the cotyledons of sugarbeet seedlings in early spring can often cause considerable damage, which occasionally is severe enough to necessitate the replanting of entire fields. In 1983 and 1984 (Tables 1 and 2), moderate flea beetle damage was re-

Table 1. Effect of various insecticide treatments on sugarbeet performance and insect control at Taber, Alberta 1983.

Insecticide	Rate (kg/ha)	Method of application	Plant stand[a] June 7-8	June 29	Sept 30	Flea beetle holes/ leaf	Maggot damage rating	Sugar (%)	Beet yield (t/ha)
Temik 10G	1.12	in-furrow	92	94	92	0.7	0.5	17.04	45.33
Lorsban 10G	1.12	in-furrow	92	91	88	2.1	0.6	17.08	43.66
Counter 15G	1.12	in-furrow	97	97	94	0.9	0.7	16.95	43.51
Furadan 10G	0.84	in-furrow	92	87	72	2.3	1.6	15.74	26.00
Temik 10G	2.25	post-emerg.	88	89	86	2.6	0.5	16.97	44.02
Lorsban 40E	2.25	post-emerg.	90	90	84	2.9	0.8	16.49	42.78
Furadan 48F	2.25	post-emerg.	92	91	86	2.4	0.6	16.98	41.02
Furadan 10G	1.72	post-emerg.	90	86	80	2.9	0.9	16.54	33.81
Counter 15G	2.25	post-emerg.	93	79	73	2.7	0.9	16.28	33.17
Untreated			92	67	46	2.2	1.8	16.03	17.79
L.S.D. (P = 0.05)			NS	6	6	0.7	0.3	0.45	4.58

[a]Plant stand x 1000 = plants per hectare.

corded. Damage ratings indicated that the in-furrow treatments of Temik 10G, Counter 15G, and Oncol 10G provided protection from feeding by this insect. Use of these insecticides would probably be adequate to protect sugarbeet plants from damage in most years and additional insecticide use for control of this pest would be unnecessary. In-furrow treatments of Furadan 10G and Lorsban 15G provided no control in 1983 and only marginal control in 1984. Flea beetle feeding had ended by the date that post-emergence treatments were applied and their efficacy could not be evaluated.

Records of plant stand early in the season provided a good measure of phytotoxicity of treatments applied during planting. Since the 1983 experiment had to be replanted, only results from 1984 and 1985 (Tables 2 and 3) were examined for this purpose. The in-furrow treatment with Counter 15G and press-wheel treatments of Broot 15G and Dyfonate 10G caused significant reduction of plant stands. Reduced plant stand in plots treated with Counter 15G had

Table 2. Effect of various insecticide treatments on sugarbeet performance and insect control at Taber, Alberta 1984.

Insecticide	Rate (kg/ha)	Method of application	Plant stand[a] May 30	Plant stand[a] June 20	Flea beetle holes/ leaf	Maggot damage rating	Sugar (%)	Beet yield (t/ha)
Oncol 10G	1.12	in-furrow	53	58	0.24	0.23	15.40	64.94
Temik 10G	1.12	in-furrow	45	49	0.14	0.16	15.35	64.30
Furadan 10G	0.84	in-furrow	46	51	0.37	0.28	14.95	62.92
Counter 15G	1.12	in-furrow	36	38	0.30	0.18	14.72	59.64
Lorsban 15G	1.12	in-furrow	41	44	0.54	0.41	14.63	57.15
Counter 15G	1.12	presswheel	44	50	0.35	0.12	15.04	62.06
Lorsban 15G	1.12	presswheel	44	44	0.61	0.40	14.65	58.09
Dyfonate 10G	1.12	presswheel	37	43	0.36	0.48	15.21	57.80
Temik 10G	2.25	post-emerg.	49	52	0.90	0.10	15.29	65.32
Furadan 48F	1.12	post-emerg.	46	51	0.96	0.26	15.22	63.46
Temik 10G	1.12	post-emerg.	48	54	0.84	0.23	15.31	62.97
Furadan 48F	2.25	post-emerg.	48	53	0.78	0.19	15.27	62.57
Oncol 30E	1.12	post-emerg.	49	52	1.06	0.27	15.48	62.08
Dyfonate 40E	1.12	post-emerg.	48	52	0.93	0.53	15.30	61.10
Lorsban 40E	1.12	post-emerg.	49	53	0.78	0.45	15.11	58.77
Lorsban 40E	2.25	post-emerg.	46	50	0.80	0.30	15.24	55.65
Untreated	----	-----------	49	43	0.73	1.17	15.47	54.29
L.S.D. (P = 0.05)			8	8	0.40	0.36	NS	6.14

[a]Plant stand x 1000 = plants per hectare.

Table 3. Effect of various insecticide treatments on sugarbeet performance and insect control at Taber, Alberta 1985.

Insecticide	Rate (kg/ha)	Method of application	Plant stand[a] June 7	Plant stand[a] July 22	Plant stand[a] Sept 26	Maggot damage rating	Sugar (%)	Beet yield (t/ha)
Furadan 10G	0.84	in-furrow	96	98	82	0.04	17.85	50.19
Oncol 10G	1.12	in-furrow	92	94	81	0.02	17.59	49.51
Temik 10G	1.12	in-furrow	91	90	78	0.00	17.92	49.14
Counter 15G	1.12	in-furrow	83	88	78	0.01	17.38	45.91
Lorsban 15G			92	81	68	0.02	17.36	44.82
Broot 15G	1.12	press-wheel	80	78	72	0.02	17.30	44.95
Dyfonate 10G	1.12	press-wheel	72	75	67	0.01	17.32	44.04
Lorsban 15G	1.12	press-wheel	97	70	62	0.10	17.26	42.14
Temik 10G	1.12	post-emerg.	95	95	81	0.00	17.79	51.32
Furadan 48F	1.12	post-emerg.	96	97	86	0.01	17.68	51.25
Oncol 30E	1.12	post-emerg	92	93	81	0.07	17.76	47.66
Lorsban 40E-HF	1.12	post-emerg.	94	92	79	0.01	17.23	43.64
Untreated	----	-----------	95	87	76	0.67	17.30	42.02
L.S.D. (P = 0.05)			6	6	6	0.08	NS	3.90

[a]Plant stand x 1000 = plants per hectare.

been observed in earlier work (3). In the 1984 experiment, however, Counter 15G was also applied as a treatment behind the press wheel. For this method of treatment plant stand was not significantly different from that in the untreated check, but was significantly greater than in plots treated with Counter 15G as an in-furrow application. It appears that the greater amount of soil between the insecticide and beet seed, which occurs using the press-wheel application method, can result in less phytotoxicity and better plant stand. None of the other treatments in 1984 and 1985 resulted in significant phytotoxicity, although it should be noted that in previous work, in-furrow treatments of Temik and Furadan occasionally caused significantly reduced stand establishment (3). In the present study, fall-ridging was used which ensured excellent seedbed moisture and provided for enhanced seed germination and plant establishment. This may have contributed to lower phytotoxicity by the insecticides. Cooke (6) reported lower phytotoxicity with soil-applied granular pesticides under good soil moisture conditions than under dry conditions.

Evaluation of possible phytotoxic effects on sugarbeets by application of post-emergence treatments is more difficult than that of at-planting treatments since SBRM feeding at time of application can also contribute to reduction of plant stand. Plots treated with granular and liquid formulations did not have significantly lower plant stand compared with the untreated check at harvest. Within 2 weeks after application of post-emergence treatments in 1985, it was observed that beets treated with Lorsban 4OE-HF (XRM-4764) had distorted leaves and a reduced rate of growth. The observed phytotoxicity may have been due to the use of a new solvent in the formulation that year.

Sugarbeet root maggot damage to beet roots was significantly reduced by each of the insecticides tested, regardless of the method of application, with the exception of the in-furrow treatment of Furadan 10G in 1983. Post-emergence applications in 1984 and 1985 were one-half the rate used in 1983 and good control of root maggot damage was still obtained. Temik, Lorsban and Oncol were equally as effective whether applied in-furrow or as a post-emergence application.

During the past five years we have observed that Furadan 10G has gradually failed to control the SBRM in commercial sugarbeet fields of southern Alberta (Whitfield, unpublished data). Reduction of efficacy by this product may be due to earlier planting dates and thus an increase in the interval between insecticide application and SBRM activity. Read and Gaul (17) in a study on the cabbage maggot, *D. brassicae* (Weideman), reported that carbofuran applied to the soil is broken down by soil-borne microorganisms. Twenty-five days after application they observed a 10% reduction in root maggot mortality and 55 days after application an 80% reduction in mortality. This may explain why Furadan 10G in-furrow was effective in 1984 and 1985, but not in 1983 when treatments were applied early in relation to the emergence of SBRM.

Except for Counter in 1983, none of the post-emergence treatments had significantly lower plant stands later in the season than the corresponding in-furrow treatments, indicating that early SBRM damage which can lead to stand reduction was controlled. Because plots were reseeded in 1983 and early season phytotoxicity of Counter 15G would have been reduced, differences in plant stand between methods of application of this chemical might be expected. It is possible that the active ingredient of Counter 15G when applied as a post-emergence treatment is not released quickly enough into the soil following sprinkler irrigation to prevent root maggot feeding and some stand loss during the season. Similarly the post-emergence treatment of Furadan 48F in 1983 resulted in significantly less stand loss than the post-emergence Furadan 10G treatment. Again, this may have been due to the Furadan 48F having been washed into the soil more quickly than the active ingredient of Furadan 10G. As a result of this information, only Temik 10G was tested in 1984 and 1985 as a post-emergence granular treatment for control of the SBRM.

In 1983, all treated plots had significantly greater yield of sugarbeets over the untreated check. In the 1984 and 1985 experiments there was no significant increase in the yield of sugarbeets for those plots treated with Lorsban, Dyfonate, Broot and Counter (in-furrow). All other treatments resulted in significant increases in yield. On the average of three years, plots treated with Temik 10G (in-furrow and post-emergence) and Furadan 48F resulted in the highest yield of beets. Plots treated with Counter and Lorsban (in-furrow) had the next highest yields. The insecticide Oncol 10G, while not yet registered for use in Canada, provided results similar to Temik and Furadan.

Reduction in percent sugar content in 1983 was observed for those treatments that incurred the greatest root maggot damage: Furadan 10G (in-furrow and post-emergence), Counter 15G (post-emergence), Lorsban 40E (post-emergence) and the untreated check. These treatments also had the lowest plant stand at harvest. Similar effects of reduced plant density on percent sugar content have been observed by other researchers investigating SBRM control (3,10,13). A logical explanation is that with a significant reduction in plant density, the amount of available nitrogen in the soil remains high late in the season and less sugar storage occurs. No differences were observed among any treatments in percent sugar content in the 1984 and 1985 experiments. During these years, SBRM caused less root damage and stand loss.

These data indicated that root damage can be reduced and significantly higher yields of sugarbeets can be achieved by use of post-emergence treatments of Furadan 48F or Temik 10G for control of the SBRM. In agricultural production it is economically and ecologically desirable to use pesticides only to the extent that they are required to reduce pest infestations to levels necessary to maintain high crop yields. Post-emergence treatments can be applied to sugarbeets after the level of SBRM infestation is known and the economic need for treatment can be established (20). Post-emergence treatments have the additional advantage of eliminating the phytotoxicity associated with at-planting treatments. Application of Furadan 48F may be preferred over use of Temik 10G because of lower cost and reduced environmental problems.

CONCLUSIONS

Good, consistent control of the SBRM was obtained with in-furrow treatments of Temik 10G, Lorsban 15G, Counter 15G, Oncol 10G; press-wheel treatments of Counter 15G, Dyfonate 10G, Broot 15G; and post-emergence treatments of Temik 10G, Furadan 48F, Oncol 30E, Lorsban 40E, and Dyfonate 40E. In-furrow treatments with Furadan 10G were effective when the interval between application date and date of SBRM activity was less than three weeks. Post-emergence applications appear to be a practical and economical method for controlling the SBRM in areas where sprinkler irrigation is available. This method has distinct advantages including efficacy, reduced cost and reduced phytotoxicity, over at-planting treatments.

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