EXPERIMENTAL INSECTICIDES FOR SUGARBEET ROOT MAGGOT CONTROL: COMBINED RESULTS FROM FOUR YEARS OF SCREENING

Mark A. Boetel, Professor
Jacob J. Rikhus, Research Specialist

Department of Entomology, North Dakota State University, Fargo, ND

Introduction:

The sugarbeet root maggot (SBRM), *Tetanops myopaeformis* (Röder) is the most economically damaging insect pest of sugarbeet in the Red River Valley (RRV) production area. Economically significant SBRM infestations are relatively common on between 50,000 and 85,000 RRV sugarbeet acres each year. A limited number of insecticide tools are currently registered by the U.S. Environmental Protection Agency (EPA) for root maggot management. Moreover, the small number of options available for SBRM control have mostly involved the same insecticide mode of action (i.e., acetylcholinesterase [ACHE] inhibition) for well over 40 years.

In the many fields where severe SBRM infestations develop each year, a common control approach involves two to three applications of ACHE-inhibiting insecticides within the same growing season to protect the crop from major economic loss. This long-term pattern of repeated use of ACHE inhibitors has exerted intense selection pressure for the development of insecticide resistance in RRV root maggot populations. As such, research on alternative tools and tactics for SBRM management is critically needed to preserve the long-term sustainability and profitability of sugarbeet production for growers affected by this pest. This experiment was carried out to achieve the following objectives: 1) screen several natural and/or botanical insecticides for efficacy at managing the sugarbeet root maggot; and 2) evaluate commercially available, EPA-labeled conventional chemical insecticides that are currently not registered for use in sugarbeet to determine if their performance would warrant future pursuit of labeling for use in the crop for SBRM control.

Materials and Methods:

This experiment was carried out on grower-owned field sites near St. Thomas (Pembina County), ND during the 2016, 2017, 2018, and 2019 growing seasons. Respective planting dates for these study years were May 10, 11, 14, and 15 May. All plots were planted with glyphosate-resistant seed (i.e., Betaseed 89RR52 during 2016 through 2018, and Betaseed 8524 in 2019). Planting was done by using a 6-row Monosem NG Plus 4 7x7 planter set to plant at a depth of 1¼ inch and a rate of one seed every 4½ inches of row length. Plots were six rows (22-inch spacing) wide with the four centermost rows treated. The outer "guard" rows (i.e., rows one and six) on each side of the plot served as untreated buffers. Each plot was 35 feet long, and 35-foot tilled alleys were maintained between replicates throughout the growing season. The experiment was arranged in a randomized complete block design with four replications of the treatments; however, data from two of the least homogeneous replicates (i.e., one from 2018 and one from 2019) in relation to the remainder of the experiment was excluded to remove unwanted variability and to allow for combined analyses of data from all four study years. As a result, all of the analyses were carried out on a total of 14 replicates.

<u>Planting-time insecticide applications</u>. Counter 20G, applied at a moderate labeled rate (7.5 lb product/ac) was used for comparative purposes as a planting-time standard chemical insecticide in this experiment. It was applied by using band (B) placement (Boetel et al. 2006), which consisted of 5-inch swaths of granules delivered through Gandy™ row banders. The granular application rate was regulated by using a planter-mounted SmartBox™ computer-controlled insecticide delivery system calibrated on the planter immediately before all applications.

Planting-time liquid insecticides screened in this trial included the following: 1) Aza-Direct (active ingredient: azadirachtin, a neem tree-derived insect antifeedant and growth disruptor); and 2) Endigo ZC (a combination insecticide containing lambda-cyhalothrin [a pyrethroid insecticide] and thiamethoxam [a neonicotinoid]). Both at-plant liquid treatments were delivered in 3-inch T-bands over the open seed furrow by using a planter-mounted, CO_2-propelled spray system equipped with TeeJet™ 400067E nozzles. The planting-time liquid insecticide delivery system was calibrated to apply a finished spray volume output of 5 GPA.

Postemergence insecticide applications. Experimental postemergence insecticide treatments in this experiment included the following sprayable liquid products: 1) Captiva (an insect repellent comprised of capsicum [pepper] extract, garlic oil, and soybean oil]); 2) Dibrom Emulsive (a conventional organophosphate insecticide), Ecozin Plus 1.2%ME (azadirachtin); 3) Evergreen Crop Protection 60-6EC (pyrethrum + a synergist), Vydate C-LV (a carbamate insecticide); and Warrior II (a pyrethroid with Zeon U.V. protection). All of these postemergence-applied experimental insecticides were compared with Lorsban Advanced as a postemergence chemical insecticide standard because chlorpyrifos is the most commonly used postemergence liquid insecticide used for SBRM control by RRV growers. In three of the four years, postemergence spray treatments were broadcast-applied at one day before peak SBRM fly activity; the only exception to this was in 2019, in which the majority of post sprays were made one day after peak SBRM fly activity). All postemergence prays were applied from a tractor-mounted, CO_2-propelled spray system equipped with an 11-ft boom that was calibrated to deliver a finished spray volume output of 10 GPA through TeeJet™ 11001VS nozzles.

All insecticide treatments involved single, stand-alone (i.e., planting-time or postemergence) applications. Specifically, there was no at-plant insecticide in plots assigned to receive a postemergence insecticide, and vice versa.

Root injury ratings: Sugarbeet root maggot feeding injury was assessed in this trial on August 1 in 2016 and 2017, and on July 31 in both 2018 and 2019. Rating procedures involved randomly selecting ten beet roots per plot (five from each of the outer two treated rows), hand-washing them, and rating them in accordance with the 0 to 9 root injury rating scale (0 = no scarring, and 9 = over ¾ of the root surface blackened by scarring or dead beet) of Campbell et al. (2000).

Harvest: Treatment performance was also compared according to sugarbeet quality and yield. Plots were harvested on September 19, 25, and 19 in 2016, 2018, and 2019, respectively, and October 2 in 2017. Foliage was removed from plots immediately before harvest by using a commercial-grade mechanical defoliator. All beets from the center two rows of each plot were extracted from the soil using a mechanical harvester, and weighed in the field using a digital scale. A random subsample of 12-18 roots was collected from each plot and sent to the American Crystal Sugar Company Tare Laboratory (East Grand Forks, MN) for sucrose content and quality analysis.

Data analysis: All data from root injury ratings and harvest samples were subjected to analysis of variance (ANOVA) using the general linear models (GLM) procedure (SAS Institute, 2012). Initial analyses indicated that there were no significant treatment × year interactions for root injury ratings (P = 0.0563), recoverable sucrose yield (P = 0. 0.5798), root yield (P = 0.1332), or percent sucrose content data (P = 0.2725). As such, four-year combined analyses were performed on all data from this experiment. Treatment means for all four response variables were separated using Fisher's protected least significant difference (LSD) test at a 0.05 level of significance.

Results and Discussion:

As mentioned above, all insecticide entries in this trial were single-component control tools (i.e., none of the planting-time insecticide treatment plots received any postemergence insecticide protection, and none of the postemergence treatment plots had any planting-time protection). This practice is not recommended in high-risk areas such as St. Thomas, where severe SBRM infestations are common. Therefore, the results of this trial should be interpreted with discretion and with the reminder that the overall goal of this research is to determine if any of these products have the potential of providing supplemental SBRM suppression or control as part of future integrated management programs involving both planting-time and postemergence insecticide applications.

The combined results for sugarbeet root maggot feeding injury in this experiment appear in Table 1. The average level of SBRM larval feeding injury recorded for the untreated check was 6.02 on the 0 to 9 scale of Campbell et al. [2000]), which indicated that moderately high SBRM pressure occurred during the 4-year duration of the experiment. All insecticide treatments provided significant reductions in SBRM feeding injury when compared to the untreated check. Despite Counter 20G being applied at a moderate labeled rate (i.e., 7.5 lb product/ac), it provided significantly greater root protection (i.e., lower SBRM feeding injury ratings) than all other insecticide treatments in the experiment. Other insecticides that provided moderately good protection from larval feeding included Endigo ZC, Vydate C-LV, and Lorsban Advanced. It should also be noted that Lorsban Advanced was applied at a moderate labeled rate (1 pt product/ac). In addition to Counter, Endigo, and Vydate, other treatments that were not significantly outperformed by Lorsban Advanced in relation to root protection from SBRM feeding injury included Dibrom, Ecozin Plus, Captiva, Evergreen Crop Protection, and Warrior II.

Table 1. *Larval feeding injury* in an evaluation of experimental at-plant and postemergence insecticides for sugarbeet root maggot control, St. Thomas, ND, 2016-2019				
Treatment/form.	**Placement[a]**	**Rate (product/ac)**	**Rate (lb a.i./ac)**	**Root injury (0-9)**
Counter 20G	B	7.5 lb	1.5	4.08 f
Endigo ZC	3” TB	4.5 fl oz	0.031	4.68 e
Vydate C-LV	1 d Post-peak Broadcast	34 fl oz	1.0	4.91 de
Lorsban Advanced	1 d Peak fly Broadcast	1 pt	0.5	5.00 cde
Dibrom	1 d Post-peak Broadcast	1 pt	1.65	5.24 bcd
Ecozin Plus 1.2% ME	1 d Post-peak Broadcast	56 fl oz	0.044	5.25 bcd
Captiva	1 d Post-peak Broadcast	2 pts		5.29 bcd
Evergreen Crop Protection	1 d Post-peak Broadcast	16 fl oz		5.31 bcd
Warrior ll	1 d Post-peak Broadcast	1.92 fl oz	0.03	5.48 bc
Aza-Direct	3” TB	56 fl oz	0.043	5.50 b
Check	---	---	---	6.02 a
LSD (0.05)				0.487

Means within a column sharing a letter are not significantly (P = 0.05) different from each other (Fisher’s Protected LSD test).
[a]B = 5-inch band at planting; 3” TB = 3-inch band over open seed furrow at planting; DIF = dribble in-furrow at planting

Yield data from this trial are shown in Table 2. The only entries that provided significant increases in both recoverable sucrose yield and root tonnage when compared to the untreated check were the planting-time application of Counter 20G (7.5 lb product/ac), the T-banded application of Endigo ZC at planting, and postemergence foliar sprays of Vydate C-LV, and Ecozin Plus. Root yield increases from these treatments, in comparison to the untreated check, ranged from 2.7 tons/ac for the Vydate application to a 3.8-ton increase from the planting-time application of Counter. Although Counter 20G-treated plots produced numerically greater sucrose and root yields than those of all other treatments in the experiment, entries that were not significantly outperformed by Counter in relation to recoverable sucrose yield included Endigo ZC, Vydate C-LV, Ecozin Plus, Warrior II, Dibrom, and Lorsban Advanced. However, it is important to also note that applications of Warrior II, Dibrom, and Lorsban Advanced did not provide significant sucrose yield increases over that recorded for the untreated check.

Table 2. *Yield parameters* from an evaluation of experimental at-plant and postemergence insecticides for sugarbeet root maggot control, St. Thomas, ND, 2016-2019							
Treatment/form.	**Placement[a]**	**Rate (product/ac)**	**Rate (lb a.i./ac)**	**Sucrose yield (lb/ac)**	**Root yield (T/ac)**	**Sucrose (%)**	**Gross return ($/ac)**
Counter 20G	B	7.5 lb	1.5	7866 a	27.5 a	15.34 a	812
Endigo ZC	3” TB	4.5 fl oz	0.031	7715 ab	27.4 a	15.36 a	772
Vydate C-LV	1 d Post-peak Broadcast	34 fl oz	1.0	7584 abc	26.4 ab	15.45 a	787
Ecozin Plus 1.2% ME	1 d Post-peak Broadcast	56 fl oz	0.044	7376 a-d	25.6 abc	15.47 a	769
Warrior ll	1 d Post-peak Broadcast	1.92 fl oz	0.03	7348 a-e	26.2 abc	15.21 a	732
Dibrom	1 d Post-peak Broadcast	1 pt	1.65	7323 a-e	25.6 abc	15.35 a	753
Lorsban Advanced	1 d Peak fly Broadcast	1 pt	0.5	7177 a-e	25.0 bc	15.46 a	746
Evergreen Crop Protection	1 d Post-peak Broadcast	16 fl oz		7035 b-e	24.5 bc	15.36 a	730
Captiva	1 d Post-peak Broadcast	2 pts		6882 cde	24.1 bc	15.34 a	706
Aza-Direct	3” TB	56 fl oz	0.043	6826 de	24.6 bc	15.11 a	667
Check	---	---	---	6652 e	23.7 c	15.21 a	660
LSD (0.05)				712.6	2.44	NS	

Means within a column sharing a letter are not significantly (P = 0.05) different from each other (Fisher’s Protected LSD test).
[a]B = 5-inch band at planting; 3” TB = 3-inch band over open seed furrow at planting; DIF = dribble in-furrow at planting

All insecticide-treated entries in this trial involved a single product application. Although this practice is not recommended for sugarbeet production in high-risk SBRM infestation areas, it was employed this trial to isolate the performance of each individual insecticide treatment. As such, all insecticide-treated plots were anticipated to sustain more SBRM feeding injury and yield loss than would be typically incurred in a grower’s commercial field. However, the results were somewhat encouraging. Most notable was the fact that two of the top four treatments, in relation to recoverable sucrose and root yield, involved alternative modes of action to the commonly used ACHE inhibitors. Endigo ZC is comprised of two active ingredients (thiamethoxam [a neonicotinoid insecticide] and lambda-cyhalothrin (a pytrethroid); whereas, the active ingredient in Ecozin Plus is azadirachtin (a plant-derived alkaloid with insecticidal properties).

Plots protected by the T-banded application of Endigo generated $772 in gross economic return per acre, which was an increase of $112/ac when compared to the untreated check. Similarly, plots treated with a single postemergence broadcast application of Ecozin Plus produced $769/ac in gross revenue, which involved a revenue improvement of $109/ac over that of the untreated check. Most of the other insecticide treatments generated revenue increases of between $46 and $127/ac when compared to the untreated check. The exception was Aza-Direct, which was not significantly different from the untreated check recoverable sucrose yield or root tonnage, and only generated $7/ac in increased gross economic return.

These results provide some encouragement regarding the future of SBRM management. Five of the experimental/alternative treatments generated numerically, albeit not statistically, more recoverable sucrose than Lorsban Advanced (the postemergence broadcast spray standard in this trial), and none of these treatments were significantly outperformed with regard to root protection or resulting yield by Counter 20G (the conventional planting-time standard). However, we remind the reader that both Counter 20G and Lorsban Advanced were applied at moderate rates, and not the maximums allowed on the respective labels of those products.

Further testing should be carried out on these and other experimental materials to identify viable alternatives to the currently used insecticides. The use of alternative insecticide active ingredients in place of the long-used ACHE inhibitors could help prevent or delay the development of insecticide resistance in SBRM populations. Products formulated with active ingredients belonging to these alternative modes of action could also provide viable tools for growers to sustainably and profitably produce sugarbeet in areas affected by this pest if the currently available conventional insecticides become unavailable in the future due to regulatory action or voluntary cancellations by their manufacturers.

References Cited:

Boetel, M. A., R. J. Dregseth, A. J. Schroeder, and C. D. Doetkott. 2006. Conventional and alternative placement of soil insecticides to control sugarbeet root maggot (Diptera: Ulidiidae) larvae. J. Sugar Beet Res. 43: 47–63.

Campbell, L. G., J. D. Eide, L. J. Smith, and G. A. Smith. 2000. Control of the sugarbeet root maggot with the fungus *Metarhizium anisopliae*. J. Sugar Beet Res. 37: 57–69.

SAS Institute. 2008. The SAS System for Windows. Version 9.2. SAS Institute Inc., 2002-2008. Cary, NC.

Acknowledgments:

We wish to thank Pete Carson, Wayne Lessard, and Austin Lessard for allowing us to conduct this research on their farms. We also appreciate the contributions of Alex Baker, Dylan Bergeron, Lukas Eisen, Katie Fronning, Bekah Hakk, Juliana Hanson, Clara Jastram, Brett Knudsen, Zane Miller, Matt Nelson, Brett Skarda, Rachel Stevens, Claire Stoltenow, and Kenan Stoltenow for their assistance with plot maintenance, sample collection, and data entry. Sincere appreciation is extended to the Sugarbeet Research and Education Board of Minnesota and North Dakota for providing significant funding support for this research. This work was also partially supported by the U.S. Department of Agriculture, National Institute of Food and Agriculture, under Hatch project number ND02398.