EXPERIMENTAL INSECTICIDE SCREENING TRIALS TO IDENTIFY SUGARBEET ROOT MAGGOT CONTROL ALTERNATIVES

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 an annual economic threat to sugarbeet production on well over 85,000 acres in the Red River Valley (RRV) growing region. Unfortunately, the geographic distribution and intensity of SBRM infestations have consistently increased over the past five years. Another concern regarding this pest is that a limited number of insecticide products are currently registered by the U.S. Environmental Protection Agency (EPA) for insect management in sugarbeet. As a result, RRV sugarbeet producers have had to rely heavily on the same insecticide mode of action (i.e., acetylcholinesterase [ACHE] inhibition) to manage this pest for well over four decades.

The commonly occurring severe root maggot infestations that occur in central and northern portions of the RRV often necessitate two to three applications of these materials each growing season to protect the crop from major economic loss. This long-term use of multiple applications of ACHE-inhibiting insecticides has exerted intense selection pressure for the development of insecticide resistance in root maggot populations in the RRV. Although no cases of SBRM resistance to these materials have been detected, research is critically needed to develop alternative materials and strategies for root maggot management to ensure the long-term sustainability and profitability of sugarbeet production for growers affected by this pest. This research involved two experiments that were carried out to achieve the following objectives: 1) test several natural and/or botanical insecticides for efficacy at managing the sugarbeet root maggot; and 2) evaluate commercially available, EPA-registered conventional chemical insecticides that are currently not registered for use in sugarbeet to determine if their performance would warrant future pursuit of labeling for sugarbeet root maggot control.

Materials and Methods:

This research involved two experiments (i.e., Study I and Study II) that were carried out on a commercial sugarbeet field site near St. Thomas (Pembina County), ND. Study I was planted on May 26 and Study II was planted on May 27, 2022, and both experiments were established with Betaseed 8961 glyphosate-tolerant sugarbeet seed 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 by 35 feet long. The four centermost rows of each plot received an assigned treatment, whereas the outer “guard” rows (i.e., rows one and six) on each side of each plot were untreated, and served as buffer rows. Thirty-five-foot-wide alleys between replicates were maintained weed-free via cultivation throughout the growing season. Both studies were arranged in a randomized complete block design with four replications of the treatments. Counter 20G (granular) insecticide was used for comparative purposes as a planting-time SBRM management standard in both experiments. Counter 20G was applied by using band (B) placement (Boetel et al. 2006), which consisted of 5-inch swaths of granules delivered through Gandy™ row banders. Granular application rates were regulated by using a planter-mounted SmartBox™ electronically-controlled insecticide delivery system calibrated on the planter immediately before all applications. Study-specific materials and methods for the two respective experiments are described below, and they are followed by descriptions of materials and methods used for root injury assessments, plot harvest, and data analyses that were common to both studies.

<u>Study I</u>: Experimental planting-time insecticides in Study I included the following: 1) Aztec 4.67G (active ingredients: tebupirimifos and cyfluthrin, an organophosphate and a pyrethroid insecticide, respectively); 2) Delegate WG (active ingredients: a combination of spinetoram-J and spinetoram-L, nicotinic acetylcholine receptor modulators); 3) Ecozin Plus 1.2%ME (active ingredient: azadirachtin, a neem tree-derived insect antifeedant and growth disruptor); 4) Index (active ingredients: chlorethoxyfos and bifenthrin, an organophosphate and a pyrethroid insecticide, respectively); and 5) Smart Choice 5G (active ingredients: also chlorethoxyfos and bifenthrin).

All planting-time liquid insecticides in Study I were delivered in 3-inch T-bands over the open seed furrow by using a planter-mounted spray system calibrated to deliver a finished spray volume output of 5 gallons per acre (GPA) through TeeJet™ 400067E nozzles. Water used as a carrier for all planting-time liquid insecticide applications in Study I was adjusted to pH 6.0 about one week before planting.

Experimental postemergence insecticides evaluated in Study I included the following sprayable liquid products: 1) Abba Ultra (active ingredient: abamectin, a chloride channel activator); 2) Delegate WG (described above); 3) Dibrom 8 Emulsive (active ingredient: naled, an organophosphate insecticide); 4) Endigo ZCX (active ingredients: thiamethoxam and lambda cyhalothrin, a neonicotinoid and a pyrethroid); and 5) Vectobac 12AS (active ingredient: *Bacillus thuringiensis* subspecies *israeliensis*, an insect-pathogenic bacterium).

All experimental postemergence insecticides were compared with Yuma 4E (active ingredient: chlorpyrifos, an organophosphate) as a postemergence insecticide standard. Postemergence sprays were broadcast-applied on June 17 (i.e., about 2 days after peak SBRM fly activity) by using 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™ 110010VS nozzles. The water used as a carrier for all postemergence liquid insecticide sprays in Study I was adjusted to pH 6.0 at least one week before applications.

<u>Study II</u>: All insecticides in Study II were applied as planting-time treatments. Counter 20G was included as a planting-time granular standard, and it was applied at its moderate rate of 7.5 lb product per acre as described above. Planting-time liquid insecticides in Study II included the following: 1) Mustang Maxx (active ingredient: zeta-cypermethrin, a pyrethroid insecticide); 2) Vantacor (active ingredient: chlorantraniliprole, a anthranilic diamide), and 3) Verimark (active ingredient: cyantraniliprole, also a anthranilic diamide). All liquid insecticides were applied by using dribble in-furrow (DIF) placement, which involved directing the spray solution into the open seed furrow through microtubes (1/4" outside diam.). Inline Teejet™ No. 18 orifice plates were used to stabilize the spray output volume, and the system was calibrated to deliver the spray solution at 5 GPA. The water used as a carrier for all liquid insecticide sprays in Study I was adjusted to pH 6.0 at least one week before applications.

<u>Root injury ratings</u>: Sugarbeet root maggot feeding injury was assessed in Study I on August 3 and in Study II on August 10, 2022 by randomly collecting ten beet roots per plot (five from each of the outer two treated rows), hand-washing them, and scoring 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 a dead plant) of Campbell et al. (2000).

<u>Harvest</u>: Treatment performance was also compared on the basis of sugarbeet yield parameters. Study I was harvested on October 5, and Study II was harvested on October 6, 2022. 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 representative subsample of 12-18 beets was collected from each plot and sent to the American Crystal Sugar Company Tare Laboratory (Moorhead, MN) for sucrose content and quality analysis.

<u>Data analysis</u>: 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), and treatment means were separated using Fisher's protected least significant difference (LSD) test at a 0.05 level of significance

Results and Discussion:

<u>Study I</u>: It is important to note that most of the insecticide entries in both of these trials were single-component (i.e., either at-plant-only or postemergence-only) control tools, which are <u>not</u> recommended as stand-alone control programs in areas such as St. Thomas, where severe SBRM infestations are common. Also, it also should be emphasized that the application timing of postemergence insecticide sprays in Study I (i.e., 2 days after peak SBRM fly activity) was not planned, but rather a result of wet early-spring soil conditions that delayed planting operations and subsequently led to atypically late seedling emergence. As a result, the postemergence insecticide applications in Study I had to be delayed until plants had emerged and were large enough for application equipment to be run through the plots without covering them with soil. The late application timing likely diminished the efficacy of all postemergence liquid spray applications in Study I.

Sugarbeet root maggot feeding injury rating data for Study I appear in Table 1. Root injury ratings in the untreated check plots averaged 6.9 on the 0 to 9 scale of Campbell et al. (2000), which indicated the presence of a high SBRM infestation for this experiment. Entries that provided the greatest levels of root protection (i.e., lowest

SBRM feeding injury ratings) included the following (listed in descending order of SBRM control performance): Counter 20G, Aztec 4.67G, Index, and Smart Choice 5G. There were no significant differences in the levels of root protection from SBRM feeding injury among those treatments. That is a very encouraging result; however, it should be pointed out that Counter 20G, the industry standard in the trial, was applied at its moderate rate (7.5 lb product/ac) rate, and not its maximum labeled rate of 8.9 lb product per acre. Other treatments in the experiment that provided statistically significant reductions in SBRM feeding injury, as compared to that recorded from the untreated check plots, included Ecozin Plus and Delegate WG; however, Counter and Aztec provided statistically greater root protection than Ecozin and Delegate. All postemergence sprays (Abba Ultra, Delegate WG, Dibrom, Endigo ZCX, and Yuma 4E), as well as the planting-time application of Vectobac, failed to provide a statistically significant reduction in SBRM feeding injury when compared to the injury that occurred in the untreated check plots.

Table 1. *Larval feeding injury ratings* from an evaluation of registered and experimental at-plant and postemergence insecticides for sugarbeet root maggot control, St. Thomas, ND, 2022 (Study I)

Treatment/form.	Placement[a]	Rate (product/ac)	Rate (lb a.i./ac)	Root injury (0-9)
Counter 20G	B	7.5 lb	1.5	3.15 e
Aztec 4.67G	B	4.45 lb		3.23 e
Index	DIF	17.1 fl oz		3.90 de
Smart Choice 5G	B	7.4 lb		4.03 de
Ecozin Plus	DIF	56 fl oz		4.95 cd
Delegate WG	DIF	6 fl oz	0.0938	5.38 bc
Abba Ultra	2 d Post-peak Broadcast	10 fl oz		5.70 abc
Yuma 4E	2 d Post-peak Broadcast	1 pt	0.5	5.78 abc
Dibrom	2 d Post-peak Broadcast	1 pt	1.65	5.98 abc
Vectobac 12AS	DIF	2 pt		6.00 abc
Delegate WG	2 d Post-peak Broadcast	6 fl oz	0.0938	6.08 abc
Endigo ZCX	2 d Post-peak Broadcast	4.5 fl oz	0.031	6.40 ab
Check	---	---	---	6.90 a
LSD (0.05)				1.273

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 at-plant band; DIF = dribble in-furrow at planting

Yield data from Study I are shown in Table 2. The highest recoverable sucrose yields in the experiment were achieved with the following treatments: 1) Counter 20G, banded at planting at its moderate rate of 7.5 lb product/ac; 2) Aztec 4.67G, banded at planting at 4.45 lb/ac; 3) Index, applied DIF at planting at 17.1 fl oz/ac; and 4) Smart Choice 5G, which was banded at planting at a rate of 7.4 lb/ac. There were no statistically significant differences in recoverable sucrose yield between those treatments; however, plots treated with either Counter, Aztec, or Index produced significantly greater sucrose yields than all other treatments in Study I, except Smart Choice. Results from treatment comparisons in relation to root yield closely corresponded to those on recoverable sucrose, with the exception that Counter 20G produced significantly greater root tonnage than Smart Choice.

In addition to providing favorable levels of SBRM control, the top three *experimental* treatments in Study I, which included Aztec, Index, and Smart Choice, also generated gross revenue increases of $629, $408, and $459 per acre, respectively, above that recorded for the untreated check. The economic benefits from most of the experimental planting-time insecticides were encouraging. Aztec, for example, generated a comparable revenue increase over the untreated check to that of Counter 20 G (i.e., $661/ac). Vectobac did not appear to provide any SBRM larval control or yield benefits in this experiment. Therefore, future work on it or similar materials should probably involve a different bacterial strain or a higher application rate, or possibly focus more on managing the adult stage of the root maggot.

Overall, the results from Study I illustrated the importance of timing for postemergence liquid insecticide applications. As shown in Tables 1 and 2, the overall performance patterns in relation to both SBRM feeding injury and yield indicated that most of the single, at-plant insecticide treatments tended to perform better than the single postemergence spray treatments. This is likely a result of the postemergence sprays having been applied two days after peak SBRM fly activity. As alluded to above in the Materials and Methods section, this was not the intended application timing for the foliar sprays. Rather, it was an unfortunate result of excessive wet soils in early spring that delayed planting and subsequently led to delayed postemergence spray applications.

Table 2. *Yield parameters* from an evaluation of registered and experimental at-plant and postemergence insecticides for sugarbeet root maggot control,, St. Thomas, ND, 2022 (Study I)							
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	9,241 a	29.3 a	16.93 a	1,731
Aztec 4.67G	B	4.45 lb		8,918 a	29.0 ab	16.55 a	1,699
Index	DIF	17.1 fl oz		8,238 a	26.8 ab	16.60 a	1,478
Smart Choice 5G	B	7.4 lb		7,474 ab	24.0 bc	16.68 a	1,529
Delegate WG	DIF	6 fl oz	0.0938	6,244 bc	20.7 cd	16.25 a	982
Ecozin Plus	DIF	56 fl oz		5,981 bc	20.2 cd	16.05 a	1,055
Endigo ZCX	2 d Post-peak Broadcast	4.5 fl oz	0.031	5,948 bc	19.6 cd	16.18 a	1,279
Dibrom	2 d Post-peak Broadcast	1 pt	1.65	5,747 bc	19.0 cd	16.35 a	948
Check	---	---	---	5,637 c	18.8 cd	16.23 a	1,070
Abba Ultra	2 d Post-peak Broadcast	10 fl oz		5,492 c	18.5 d	16.13 a	898
Vectobac 12AS	DIF	2 pt		5,233 c	17.8 d	15.98 a	922
Delegate WG	2 d Post-peak Broadcast	6 fl oz	0.0938	4,854 c	16.1 d	16.33 a	892
Yuma 4E	2 d Post-peak Broadcast	1 pt	0.5	4,793 c	16.2 d	16.13 a	931
LSD (0.05)				1,783.4	5.24	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 at-plant band; DIF = dribble in-furrow at planting

It should be pointed out that, due to space constraints, just one industry standard at-plant insecticide and one standard foliar liquid product could be included in Study I. Moderate rates of Counter 20G (i.e., 7.5 lb/ac) and Yuma 4E (i.e., 1 pt/ac) each were chosen as standards because the goal of this work was to determine if any prospective experimental insecticide product would provide at least moderate SBRM control that was comparable to Counter or Yuma. Therefore, the encouraging results achieved with several experimental insecticides in comparison to these insecticides should be understood within this context.

Another important consideration regarding in Study I was that all insecticide-treated entries were single-application treatments, which is never recommended for SBRM management under the high to severe root maggot pressure that typically develops in the northern RRV. The overall goal of this experiment was simply to determine if any of the experimental insecticides tested have potential to provide a measurable level of root protection and associated yield benefits in relation to managing this pest. Once candidate insecticide materials with such potential are identified, future research will focus on integrating them into control programs that may include both planting-time insecticide protection (i.e., a granular, sprayable liquid, or seed treatment insecticide) and postemergence additive protection to optimize SBRM management methodology.

Study II: Plant stand data from Study II appear in Table 3. At the first stand count, which was conducted at 25 days after planting (DAP), excellent plant populations were recorded for most treatments, except those treated at planting with either Mustang Maxx or the tank-mixed combination of Mustang Maxx plus Exponent (the insecticide synergist). Surprisingly, both of those treatments had significantly lower average plant stands than the untreated check. The reason for those stand deficiencies is unclear at this point, and bears further investigation.

At 34 DAP, the highest stand counts were observed in plots treated at planting with either Counter 20G, Verimark at 10 fl oz/ac, or Verimark at 5 oz/ac. There were no significant differences among those treatments, but each had significantly greater plant stands than all other treatments in Study II. Other treatments that resulted in significantly greater plant stands than those recorded in the untreated check plots included Mustang Maxx (i.e., with and without Exponent), and the high (2.5 fl oz/ac) rate of Vantacor. The low (1.2 fl oz/ac) rate of Vantacor was the only insecticide treatment that failed to provide a significant level of plant survival when compared to the untreated check at 34 DAP.

In stand counts conducted at 52 DAP, all insecticide treatments, except Vantacor at its low (i.e., 1.2 fl oz/ac) rate resulted in significantly greater surviving plant stands in comparison to the untreated check. The highest stands were recorded in plots treated with Counter 20G or Verimark (i.e., either 5 or 10 fl oz/ac). The combination treatment of Mustang Maxx plus Exponent had numerically greater average plant stands than when Mustang was applied without the synergist, which suggested that Exponent could have been providing some performance improvement, but the difference was not statistically significant.

Table 3. ***Plant stand counts*** **from an evaluation of registered and experimental planting-time granular and liquid insecticides for sugarbeet root maggot control, St. Thomas, ND, 2022 (Study II)**						
Treatment/form.	**Placement[a]**	**Rate (product/ac)**	**Rate (lb a.i./ac)**	**Stand count[b] (plants / 100 ft)**		
				25 DAP[c]	**34 DAP[c]**	**52 DAP[c]**
Counter 20G	B	7.5 lb	1.5	223.9 a	226.8 a	214.3 a
Verimark	DIF	10 fl oz	0.13	224.5 a	221.6 a	213.2 a
Verimark	DIF	5 fl oz	0.065	220.2 a	220.2 a	199.8 ab
Mustang Maxx + Exponent	DIF	4 fl oz 8 fl oz	0.025	195.5 c	188.4 b	179.1 bc
Mustang Maxx	DIF	4 fl oz	0.025	209.3 b	194.6 b	155.0 cd
Vantacor	DIF	2.5 fl oz	0.098	221.4 a	187.1 b	139.3 d
Vantacor	DIF	1.2 fl oz	0.047	217.0 ab	180.0 bc	134.5 de
Check	---	---	---	221.3 a	167.1 c	107.5 e
LSD (0.05)				10.61	15.01	30.48

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; DIF = dribble in-furrow at planting
[b]Surviving plant stands were counted on 3, 22, and 29 June, 2022 (i.e., 25, 34, and 52 days after planting [DAP], respectively).

As shown in Table 4, root maggot feeding injury in the untreated check plots of Study II averaged 7.15 on the 0 to 9 scale of Campbell et al. (2000), which suggested the presence of a relatively high SBRM infestation for this research. Most insecticide-based treatments in the experiment resulted in significant reductions in SBRM feeding injury when compared to the untreated check.

The lowest average SBRM feeding injury in Study II was observed in plots treated at planting with Counter 20G banded at its moderate rate of 7.5 lb product per acre. This treatment was superior to all other insecticides in Study II with regard to protection from SBRM larval feeding injury. However, favorable performance was achieved by Verimark at both application rates (i.e., 5 and 10 fl oz/ac), and Mustang Maxx when it was tank mixed with Exponent. Interestingly, the inclusion of Exponent with Mustang Maxx resulted in significantly greater root protection than when the Exponent was excluded.

Although not significant, plots treated with Vantacor at 2.5 fl oz per acre had numerically lower SBRM feeding injury than those that received the Vantacor at 1.2-oz rate. Root injury ratings in plots treated with the low rate of Vantacor were not statistically different from those in the untreated check plots.

Table 4. ***Larval feeding injury ratings*** **from an evaluation of registered and experimental planting-time granular and liquid insecticides for sugarbeet root maggot control, St. Thomas, ND, 2022 (Study II)**				
Treatment/form.	**Placement[a]**	**Rate (product/ac)**	**Rate (lb a.i./ac)**	**Root injury (0-9)**
Counter 20G	B	7.5 lb	1.5	2.65 e
Verimark	DIF	5 fl oz	0.065	3.85 d
Mustang Maxx + Exponent	DIF	4 fl oz 8 fl oz	0.025	4.10 d
Verimark	DIF	10 fl oz	0.13	4.15 d
Mustang Maxx	DIF	4 fl oz	0.025	5.50 c
Vantacor	DIF	2.5 fl oz	0.098	5.73 b
Vantacor	DIF	1.2 fl oz	0.047	6.38 ab
Check	---	---	---	7.15 a
LSD (0.05)				0.848

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; DIF = dribble in-furrow at planting

Yield results from Study II appear in Table 5. Performance patterns with regard to treatment impacts on yield parameters in this trial corresponded closely with those observed in SBRM feeding injury rating results, and are reason for optimism regarding the future of managing this pest. Plots treated with the industry standard insecticide, Counter 20G, at its moderate rate (7.5 lb product/ac) produced the highest recoverable sucrose and root yields in the experiment, and generated $731/ac greater gross economic return than the untreated check. Verimark treatments also resulted in excellent sucrose and root yields that were not statistically different from those from the Counter-treated plots.

Table 5. *Yield parameters* from an evaluation of registered and experimental planting-time granular and liquid insecticides for sugarbeet root maggot control, St. Thomas, ND, 2022 (Study II)							
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	8,264 a	26.7 a	16.60 ab	1,520
Verimark	DIF	10 fl oz	0.13	7,840 ab	24.5 ab	16.95 a	1,484
Verimark	DIF	5 fl oz	0.065	7,540 ab	24.5 ab	16.50 bcd	1,379
Mustang Maxx + Exponent	DIF	4 fl oz 8 fl oz	0.025	7,132 b	23.2 b	16.58 abc	1,302
Mustang Maxx	DIF	4 fl oz	0.025	5,775 c	19.0 c	16.35 b-e	1,040
Vantacor	DIF	1.2 fl oz	0.047	4,806 d	15.9 d	16.18 de	860
Vantacor	DIF	2.5 fl oz	0.098	4,733 d	15.7 d	16.20 cde	848
Check	---	---	---	4,460 d	15.0 d	16.08 e	789
LSD (0.05)				954.6	2.94	0.384	

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; DIF = dribble in-furrow at planting

Similar to the observations from SBRM feeding injury assessments, tank mixing Mustang Maxx with Exponent resulted in significantly (23.5%) greater recoverable sucrose yield and an increase of 4.2 tons per acre in root yield in comparison to Mustang applied without the insecticide synergist. Combining Mustang Maxx and Exponent also resulted also resulted in a gross revenue increase of $262 per acre when compared to Mustang-treated plots where Exponent was excluded.

It is encouraging that the experimental treatments involving Verimark in Study II provided similar levels of root maggot control, in relation to root protection from SBRM feeding injury, yield, and revenue, to that of the moderate rate of Counter 20G. The fact that the insecticide synergist, Exponent significantly improved the performance of Mustang Maxx is also promising.

Overall, the findings of these two experiments suggest that these new insecticide approaches may have value as components of multi-insecticide programs for managing high SBRM infestations in the future. Although some of the experimental treatments achieved comparable performance levels to those observed with industry standards (e.g., Counter 20G, Mustang Maxx, Yuma 4E) in these two studies, it should be repeated that Counter (both studies) and Yuma (Study I) were applied at moderate rates, not their maximum use rates. As such, further testing should be carried out on these and other experimental materials to identify potential alternatives to the currently used products. Alternative insecticide options could help prevent or delay the development of insecticide resistance in SBRM populations to currently used chemistries, and could also provide viable tools for growers to sustainably and profitably manage this pest if currently available conventional insecticides become unavailable due to regulatory action.

Finally, it should also be noted that Yuma 4E, which contains the active ingredient chlorpyrifos, was included in this research for comparative purposes. All food crop uses of chlorpyrifos-containing insecticide products, including Yuma 4E, have been cancelled by the U.S. Environmental Protection Agency. Therefore, the application of such products *is against the law*. The application of any product containing chlorpyrifos could result in a substantial fine and condemnation of the affected field(s), as well as condemnation and disposal of any piles containing roots harvested from those fields.

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. 2012. The SAS System for Windows. Version 9.4. SAS Institute Inc., 2002-2012. Cary, NC.

Acknowledgments:

The authors greatly appreciate Wayne and Austin Lessard for allowing us to conduct this research on their farm. Sincere gratitude is extended to the Sugarbeet Research and Education Board of Minnesota and North Dakota for providing significant funding to support this project. We also appreciate the contributions of Nick Antonoplos, Emma Harmsen, Grace Harmsen, and Margaret Huettl for assistance with plot maintenance and root sample collection. This work was also partially supported by the U.S. Department of Agriculture, National Institute of Food and Agriculture, under Hatch project number ND02374.