A 3-YEAR ASSESSMENT OF POSTEMERGENCE LIQUID INSECTICIDE RATES, TIMING, AND PRODUCT ROTATIONS FOR SUGARBEET ROOT MAGGOT CONTROL

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 a major economic pest of sugarbeet in the Red River Valley (RRV) of North Dakota and Minnesota. Sugarbeet root maggot populations in the RRV have been increasingly problematic for many growers during much of the past decade. The relatively common occurrence of high SBRM infestations, and recent increases in the pest's geographic range, suggest that growers will need to be more aggressive with SBRM management to ensure profitability from their sugarbeet crop.

Pest management programs in areas at high risk for damaging SBRM infestations usually begin with either a granular insecticide, a sprayable liquid insecticide, or an insecticidal seed treatment at planting, and they are often followed by one or more additive postemergence insecticide applications if justified by SBRM fly activity levels. The most commonly used approach for postemergence root maggot control in the RRV is a broadcast application of a sprayable liquid insecticide product.

Effective in 2010, the U.S. Environmental Protection Agency required that labeling for all sprayable liquid insecticide products containing the active ingredient chlorpyrifos (e.g., Lorsban 4E, Lorsban Advanced, and all generic versions) include a 10-day reapplication interval. This requires a 10-day period between successive applications of any sprayable liquid insecticide product that contains chlorpyrifos as its active ingredient. However, the potential impact of this restriction, which lengthened the reapplication interval by three days, on efficacy of chlorpyrifos-based control programs was not known. It has been thought that this restriction could impair growers' ability to effectively manage the SBRM with chlorpyrifos-based products, because high fly activity periods usually only persist for about seven days. In an effort to address this potential problem, research was undertaken to achieve the following objectives regarding postemergence SBRM management: 1) determine the most effective timing schemes for repeated applications of Lorsban Advanced sprays that adhere to its 10-day reapplication restriction; 2) assess the impact of application rate on Lorsban Advanced performance; and 3) evaluate Mustang Maxx as a single postemergence tool and as rotated with Lorsban Advanced applications for postemergence SBRM control.

Materials and Methods:

This field experiment was conducted near St. Thomas (Pembina County), ND during the 2017, 2018, and 2019 growing seasons. Betaseed 89RR52 glyphosate-resistant seed was used for all treatments in 2017 and 2018, and Betaseed 8524 (also glyphosate-resistant) seed was used in 2019. Planting dates were 11, 10, and 15 May in 2017, 2018, and 2019, respectively. All plots were planted using a 6-row Monosem NG Plus 4 7x7 planter set to deliver seed 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. No insecticide was applied to the outer "guard" rows (i.e., rows one and six) of each plot, as those rows 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 three replications of the treatments.

<u>Planting-time insecticide applications</u>. Planting-time applications of Counter 20G were 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 planter-mounted SmartBox™ computer-controlled insecticide delivery system that had been calibrated on the planter before all applications.

<u>Postemergence insecticide applications.</u> Additive postemergence insecticides used included Lorsban Advanced and Mustang Maxx. Treatments that included postemergence applications involved both single and double postemergence spray applications at varying rates. Average postemergence spray applications were made between two, four, and six days ahead of ("Pre-peak") SBRM fly activity (i.e., between 31 May and 14 June), and

between one and eight days after ("Post-peak") peak fly activity (i.e., between 8 and 24 June). Liquid insecticide solutions were delivered with a tractor-mounted CO_2-propelled spray system equipped with TeeJet™ 110015VS nozzles calibrated to deliver applications in a finished output volume of 10 GPA.

Root injury ratings: Sugarbeet root maggot feeding injury was assessed each year, with ratings being done on 1 August, 31 July, and 30 July in 2017, 2018, and 2019, respectively. Rating procedures consisted of 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 dead beet) of Campbell et al. (2000).

Harvest: Treatment performance was also compared on the basis of sugarbeet yield parameters. Plots were harvested on 2 October in 2017, 24 September in 2018, and on 19 September in 2019. Harvest procedures began with removal of foliage from all plots immediately before harvest by using a commercial-grade mechanical defoliator. Immediately following defoliation, all beets from the center two rows of each plot were extracted from 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 (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 ($P = 0.2583$), recoverable sucrose yield (P = 0. 0.1507), root yield ($P = 0.0861$), or percent sucrose content data ($P = 0.8346$). As such, three-year combined analyses were performed on all data from this experiment. Treatment means for all response variables were separated using Fisher's protected least significant difference (LSD) test at a 0.05 level of significance.

Results and Discussion:

Averaged over the three years of this experiment, root maggot feeding injury ratings in the untreated check plots averaged 6.11 on the 0 to 9 scale of Campbell et al. (2000) (Table 1). This indicated that, across years, the SBRM infestations present for this trial were considered moderate. Despite larval feeding pressure only being moderate, all insecticide treatments, including single-, dual-, and triple-insecticide application programs, resulted in significant reductions in SBRM feeding injury when compared to that in the untreated check plots. In nearly all cases, the addition of a postemergence rescue insecticide application provided a significant improvement in protection from SBRM larval feeding injury. The only postemergence components of dual-application (i.e., planting-time plus postemergence) treatments that did significantly improve root protection when compared to similar treatments that only received the planting-time treatment were: 1) a single postemergence application of Lorsban Advanced at the lower (1 pt product/ac) rate; and 2) a single application of Mustang Maxx (4 oz/ac).

Nearly all treatments that included the addition of two postemergence insecticide applications (i.e., either Lorsban Advanced applied twice, or a combination of Lorsban Advanced followed by an application of Mustang Maxx), were statistically superior in reducing SBRM feeding injury when compared to similar treatments that only included the planting-time application of Counter 20G. The following were the only exceptions to this: 1) a dual postemergence application of Lorsban Advanced at 1 pt/ac, where the post sprays were begun later (i.e., 4 days before peak fly activity rather than 6 days pre-peak); and 2) in a rotation of Lorsban Advanced and Mustang Maxx when the Mustang was applied first.

These findings suggest that growers in high-risk areas, where the need for a second post spray is anticipated, should consider applying their first Lorsban spray at least five to six days before peak fly activity, and be prepared to make a second application about ten days later. Another advisable approach is to integrate their chlorpyrifos-based postemergence control strategy with the addition of Mustang Maxx or another pyrethroid insecticide (e.g., Asana); however, the first insecticide in such rotations should involve chlorpyrifos or a similar-performing product. General trends in this trial also suggested that using the maximum rate (2 pts/ac) of Lorsban Advanced tended to provide more root protection than the 1-pt rate. Similarly, the 8.9-lb rate of Counter appeared to be slightly more effective than 7.5 lb; however, none of these differences were statistically significant.

One additional finding from this trial that bears noting is that the more simple SBRM management program comprised of a planting-time application of Counter 20G at its maximum labeled rate (8.9 lb/ac) plus a single postemergence application of Lorsban Advanced at its highest labeled rate (2 pts/ac) was significantly outperformed by any other insecticide program in this trial.

Table 1. ***Larval feeding injury*** **in an assessment of postemergence insecticide spray timing, rate, and frequency impacts on sugarbeet root maggot control, St. Thomas, ND, 2017-2019**				
Treatment/form.	**Placement[a]**	**Rate (product/ac)**	**Rate (lb a.i./ac)**	**Root injury (0-9)**
Counter 20G + Lorsban Advanced + Lorsban Advanced	B 6 d Pre-peak Broadcast 4 d Post-peak Broadcast	7.5 lb 2 pts 2 pts	1.5 1.0 1.0	2.57 d
Counter 20G + Lorsban Advanced + Lorsban Advanced	B 4 d Pre-peak Broadcast 6 d Post-peak Broadcast	7.5 lb 2 pts 2 pts	1.5 1.0 1.0	2.63 d
Counter 20G + Lorsban Advanced	B 2 d Pre-peak Broadcast	8.9 lb 2 pts	1.8 1.0	2.63 d
Counter 20G + Lorsban Advanced + Mustang Maxx	B 2 d Pre-peak Broadcast 3 d Post-peak Broadcast	7.5 lb 1 pt 4 fl oz	1.5 0.5 0.025	3.03 cd
Counter 20G + Lorsban Advanced + Lorsban Advanced	B 6 d Pre-peak Broadcast 4 d Post-peak Broadcast	7.5 lb 1 pt 1 pt	1.5 0.5 0.5	3.06 cd
Counter 20G + Lorsban Advanced	B 2 d Pre-peak Broadcast	7.5 lb 2 pts	1.5 1.0	3.19 cd
Counter 20G + Mustang Maxx + Lorsban Advanced	B 2 d Pre-peak Broadcast 3 d Post-peak Broadcast	7.5 lb 4 fl oz 1 pt	1.5 0.025 0.5	3.20 cd
Counter 20G + Lorsban Advanced + Lorsban Advanced	B 4 d Pre-peak Broadcast 6 d Post-peak Broadcast	7.5 lb 1 pt 1 pt	1.5 0.5 0.5	3.28 cd
Counter 20G + Lorsban Advanced	B 2 d Pre-peak Broadcast	7.5 lb 1 pt	1.5 0.5	3.66 bc
Counter 20G	B	8.9 lb	1.8	3.67 bc
Counter 20G + Mustang Maxx	B 2 d Pre-peak Broadcast	7.5 lb 4 fl oz	1.5 0.025	3.70 bc
Counter 20G	B	7.5 lb	1.5	4.14 b
Check	---	---	---	6.11 a
LSD (0.05)				0.746

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; Post Broad = postemergence broadcast

Yield results and associated gross economic returns from this trial are presented in Table 2. All single-, dual- and triple-insecticide control programs provided significant increases in both recoverable sucrose yield and root tonnage. As observed with root injury rating data, excellent sucrose and root yields resulted from treatment combinations that included at least one postemergence application of Lorsban Advanced at its high labeled rate (2 pts product/ac). The highest root tonnage yield was achieved by applying Counter 20G at 8.9 lb/ac, and following that with one postemergence application of Lorsban Advanced at 2 pts/ac. However, the best overall treatments in this trial with regard to recoverable sucrose yield included the following (listed in descending order of performance with regard to sucrose yield):

1) planting-time Counter 20G at 7.5 lb/ac + two 2-pt/ac postemergence applications of Lorsban Advanced (6 d pre-peak and 4 d post-peak);
2) planting-time Counter 20G at 7.5 lb/ac + two 1-pt/ac postemergence applications of Lorsban Advanced (6 d pre-peak and 4 d post-peak);
3) planting-time Counter 20G at 7.5 lb/ac + two 2-pt/ac postemergence applications of Lorsban Advanced (4 d pre-peak and 6 d post-peak);
4) planting-time Counter 20G at 8.9 lb/ac + one 2-pt/ac postemergence application of Lorsban Advanced (3 d pre-peak);
5) planting-time Counter 20G at 7.5 lb/ac + 1 pt/ac of Lorsban Advanced (2 d pre-peak) + 4 fl oz/ac of Mustang Maxx (3 d post-peak); and
6) planting-time Counter at 7.5 lb/ac + two 1-pt/ac postemergence applications of Lorsban Advanced (4 d pre-peak and 6 d post-peak).

There were no significant differences among the top six treatments with regard to recoverable sucrose yield or root tonnage. However, the best overall performing treatment, in considering protection from SBRM feeding injury, recoverable sucrose yield, and resulting gross revenue was the combination of planting-time Counter 20G at 7.5 lb/ac plus two 2-pt/ac applications of Lorsban Advanced, applied in succession at 6 days pre-peak and 4 days after peak SBRM fly activity. This combination generated $371/ac more gross revenue than the untreated check plots, and the two additional applications of Lorsban Advanced combined to provide a total of $241/ac more revenue than that generated by the stand-alone application of the base treatment (i.e., Counter 20G at 7.5 lb product per acre).

Table 2. *Yield parameters* from an assessment of postemergence insecticide spray timing, rate, and frequency impacts on sugarbeet root maggot control, St. Thomas, ND, 2017-2019

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 + Lorsban Advanced + Lorsban Advanced	B 6 d Pre-peak Broadcast 4 d Post-peak Broadcast	7.5 lb 2 pts 2 pts	1.5 1.0 1.0	10,333 a	33.88 ab	16.63 a	$1,188
Counter 20G + Lorsban Advanced + Lorsban Advanced	B 6 d Pre-peak Broadcast 4 d Post-peak Broadcast	7.5 lb 1 pt 1 pt	1.5 0.5 0.5	10,182 ab	33.25 a-d	16.61 a	$1,178
Counter 20G + Lorsban Advanced + Lorsban Advanced	B 4 d Pre-peak Broadcast 6 d Post-peak Broadcast	7.5 lb 2 pts 2 pts	1.5 1.0 1.0	10,168 ab	33.96 a	16.46 a	$1,136
Counter 20G + Lorsban Advanced	B 2 d Pre-peak Broadcast	8.9 lb 2 pts	1.8 1.0	10,015 abc	34.14 a	16.13 a	$1,082
Counter 20G + Lorsban Advanced + Mustang Maxx	B 2 d Pre-peak Broadcast 3 d Post-peak Broadcast	7.5 lb 1 pt 4 fl oz	1.5 0.5 0.025	9,896 a-d	33.60 abc	16.14 a	$1,076
Counter 20G + Lorsban Advanced + Lorsban Advanced	B 4 d Pre-peak Broadcast 6 d Post-peak Broadcast	7.5 lb 1 pt 1 pt	1.5 0.5 0.5	9,679 a-d	32.26 a-e	16.40 a	$1,085
Counter 20G + Lorsban Advanced	B 2 d Pre-peak Broadcast	7.5 lb 2 pts	1.5 1.0	9,569 bcd	32.67 a-d	16.11 a	$1,031
Counter 20G + Mustang Maxx	B 2 d Pre-peak Broadcast	7.5 lb 4 fl oz	1.5 0.025	9,564 bcd	31.88 cde	16.43 a	$1,072
Counter 20G + Mustang Maxx + Lorsban Advanced	B 2 d Pre-peak Broadcast 3 d Post-peak Broadcast	7.5 lb 4 fl oz 1 pt	1.5 0.025 0.5	9,550 bcd	32.38 a-d	16.11 a	$1,041
Counter 20G + Lorsban Advanced	B 2 d Pre-peak Broadcast	7.5 lb 1 pt	1.5 0.5	9,407 cde	31.94 b-e	16.11 a	$1,023
Counter 20G	B	8.9 lb	1.8	9,241 de	31.43 de	16.21 a	$1,002
Counter 20G	B	7.5 lb	1.5	8,845 e	30.33 e	16.08 a	$947
Check	---	---	---	7,636 f	26.17 f	15.91 a	$817
LSD (0.05)				702.8	2.35	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; Post Broad. = postemergence broadcast

As observed in root injury rating results, general patterns of performance with regard to yield parameters suggested the following conclusions: 1) a SBRM control program comprised of a moderate rate (i.e., 7.5 lb product/ac) of Counter 20G plus two postemergence sprays of Lorsban Advanced at its high rate (2 pts/ac) is an effective approach that should provide excellent root protection and resulting yield and revenue; 2) the first of two postemergence sprays of chlorpyrifos (i.e., Lorsban Advanced or 4E, or a generic equivalent) should be applied early (i.e., about 6 days before peak fly); 3) a simple SBRM control program involving Counter 20G at its high labeled rate (8.9 lb/ac) plus a single application of a chlorpyrifos spray can provide good control and resulting yield/revenue benefits; and 4) rotating successive postemergence insecticide applications by first applying a chlorpyrifos-based product, then following it within about 4 to 5 days with Mustang Maxx or another pyrethroid product (e.g., Asana XL) should be an effective SBRM control strategy that will also help prevent or delay insecticide resistance development in SBRM populations. NOTE: results from this trial and from previous evaluations suggest that, in rotations between chlorpyrifos and pyrethroid insecticides for SBRM control, applying the chlorpyrifos first (e.g., two to three days before peak fly activity) in the scheme.

Overall, most of the SBRM control programs evaluated in this experiment, especially those involving dual- and triple-component insecticide applications, provided effective SBRM control that resulted in major yield and revenue benefits. Another general conclusion that can be drawn is that the root protection, yield, and revenue benefits from additive postemergence insecticides demonstrate that they are cost-effective tools that easily pay for themselves, even under moderate SBRM larval infestations.

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