EVALUATION OF MIDAC FC® AND BIFENDER FC® FOR SUGARBEET ROOT MAGGOT CONTROL

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Introduction:

The sugarbeet root maggot (SBRM), *Tetanops myopaeformis* (Röder), is a key insect pest of sugarbeet in the Red River Valley (RRV) growing area. Red River Valley sugarbeet producers typically manage the SBRM by using a two-pronged approach involving planting-time protection with a granular, liquid, or seed-applied insecticide, and following it with at least one postemergence insecticide application to avoid major yield and revenue loss.

For well over four decades, chemical control of the SBRM has involved using insecticides from the same mode of action, acetylcholinesterase (ACHE) inhibition because a limited number of insecticide products have been commercially available for use in the crop for several decades. This long-term, repeated use of ACHE inhibitor insecticides has exerted a considerable amount of selection pressure for the development of ACHE insecticide resistance development in RRV sugarbeet root maggot populations.

In August of 2021, the U.S. Environmental Protection Agency (EPA) revoked all food crop tolerances for chlorpyrifos, which has been the most commonly used postemergence insecticide active ingredient for postemergence SBRM control for several years. Therefore, it is critical that non-ACHE insecticide options be pursued to manage this serious economic pest. In 2019, EPA approved Midac FC for registered use in sugarbeet and potato. Although the current EPA-issued Midac FC label does not specifically list sugarbeet root maggot as a target pest, Vive Crop Protection has issued a Section 2(ee) recommendation for planting-time applications of Midac for SBRM control. The 2(ee) is a legal designation, offered to end-users by the registrant, as permitted by EPA through statutory authority under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1910. The FIFRA 2(ee) designation allows a user to apply "*a pesticide against any target pest not specified on the labeling if the application is to the crop, animal, or site specified on the labeling, unless the Administrator has required that the labeling specifically state that the pesticide may be used only for the pests specified on the labeling after the Administrator has determined that the use of the pesticide against other pests would cause an unreasonable adverse effect on the environment*." This provides legal permission for producers and other applicators to use Midac FC for sugarbeet root maggot management in sugarbeet. However, they must be in physical possession of the published 2(ee) recommendation/product bulletin at the time the product is being applied.

The active ingredient in Midac FC imidacloprid, is a neonicotinoid insecticide. This class involves an entirely different mode of action (i.e., antagonism of the postsynaptic nicotine acetylcholine receptor in the central nervous system) for insect control from that of the long-used ACHE-based insecticides. Other neonicotinoid products have been used as insecticidal seed treatments for insect management in sugarbeet since 2008. One purported benefit of Midac FC is its apparent compatibility for tank mixing with starter fertilizer formulations. Inclusion of starter fertilizer with sugarbeet planting is commonly practiced by producers in the Red River Valley growing area, but little is known about its potential impacts, either positive or negative, on agronomic responses such as insecticide performance, plant safety, and resulting crop yield.

The key objective of this experiment was to evaluate the efficacy of Midac FC and Bifender FC for sugarbeet root maggot control. Secondarily, this research was conducted to determine the impacts of combining Midac with 10-34-0 starter fertilizer, and also integrating it with Poncho Beta insecticidal seed treatment for enhancing single-pass insect management in sugarbeet. A third objective was to monitor for potential negative impacts (e.g., phytotoxicity) from dual- and multiple-component combinations of Midac, Poncho Beta, and 10-34-0 starter fertilizer.

Materials and Methods:

This field experiment was conducted near St. Thomas in rural Pembina County, ND during the 2021 growing season. Betaseed 8961 glyphosate-resistant seed was used for all treatments in the trial, and all plots were planted on May 13, 2021 by 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. Insecticide was excluded from each of the outside rows (i.e., rows 1 and 6) of the planter, and those "guard rows" served as untreated buffers. Each plot was 35 feet long, and 35-foot alleys between replicates were maintained weed-free by using periodic cultivation throughout the growing season. The experiment was arranged in a randomized complete block design with four replications of the treatments.

Midac FC and VCP034 (an experimental insecticide) were applied using dribble in-furrow (DIF) placement by orienting microtubes (1/4" outside diam.) directly into the open seed furrow. Inline Teejet™ No. 24 orifice plates were used to stabilize the output rate of the spray solutions from the microtubes. Bifender FC was applied by using both DIF and T-band placement. T-band placement was achieved by orienting the output fan of a conventional TeeJet™ 450067E nozzle directly perpendicular to each planter row, and adjusting nozzle height to achieve a 3-inch band over the open seed furrow. Most at-plant treatments included 10-34-0 fertilizer (i.e., 10, 34, and 0% nitrogen, phosphorus, and potassium, respectively), which was diluted to a 3:2 gallon ratio of fertilizer to water. Water used for these solutions was adjusted to pH 6.0 several days before use. All planting-time liquid applications were delivered in a finished spray volume output of 5 GPA.

Non-fertilizer entries included Counter 20G at two application rates (i.e., 7.5 and 8.9 lb product/ac), and a true untreated check. The 7.5-lb rate of Counter and a control were also included with a concurrent application of the fertilizer/water solution. 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™ insecticide delivery system that had been calibrated on the planter before all applications.

Plant Stand Counts: To determine treatment impacts on seedling emergence and survival throughout the growing season, surviving plant stands were counted on 3, 22, and 29 June, 2021 (i.e., 21, 40, and 47 days after planting [DAP]), respectively. Plant stand assessments involved counting all living plants within each 35-ft-long row. Raw stand counts were then converted to plants per 100 linear row feet for the analysis.

Root injury ratings: Sugarbeet root maggot feeding injury ratings were conducted on August 4. Sampling 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: Plots were harvested on September 22. Immediately (i.e., within one hour) before harvest, all foliage was removed from plots by using a commercial-grade mechanical defoliator. All beets from the center two rows of each plot were then 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) according to the general linear models (GLM) procedure (SAS Institute, 2012). Treatment means were compared by using Fisher's protected least significant difference (LSD) test at a 0.05 alpha level for declaring significance.

Results and Discussion:

Table 1 includes plant stand counts from three dates. Treatments are listed in descending order of surviving plant stand at the final count. Thus, careful attention is required to assess stand count comparisons from the first two count dates. The highest plant densities at the first stand count (i.e., 21 DAP) were observed in the true untreated control plots; however, other treatments, which were not statistically different in surviving stand at 21 DAP included both at-plant-only (i.e., no starter fertilizer) applications of Counter 20G, and the 3" T-band of Bifender FC. All other treatments had significantly lower surviving plant stands than the true untreated check. This suggests that those treatments, which included the DIF application of Bifender, all Midac-based treatments, both Counter-based treatments that included a starter fertilizer, and the treatment of Poncho Beta plus fertilizer, had statistically significant negative impacts on stand establishment. The treatment consisting of Poncho Beta and starter fertilizer also had significantly lower plant stands at 21 DAP than the fertilizer-only check. Additionally, plots that received the 10-34-0 starter fertilizer-only control had statistically fewer plants per 100 ft than the true untreated check, suggesting that the fertilizer was likely an important factor in the observation of reduced stands in several these treatments.

Table 1. *Plant stand counts* from an evaluation of Midac® and Bifender® insecticides for sugarbeet root maggot control, St. Thomas, ND, 2021

Treatment/form.[a]	Placement[b]	Rate (product/ac)	Rate (lb a.i./ac)	Stand count[c] (plants / 100 ft)		
				21 DAP[c]	40 DAP[c]	47 DAP[c]
Counter 20G	B	7.5 lb	1.5	200.4 ab	183.0 abc	206.3 a
Counter 20G	B	8.9 lb	1.8	210.7 a	197.9 a	197.9 ab
Midac FC + 10-34-0 + Bifender FC	DIF 1 d Pre-peak Broadcast	13.6 fl oz 5 GPA 7.3 fl oz	0.18 0.1	180.4 cd	188.6 abc	192.7 abc
Bifender FC + 10-34-0	3" TB	7.3 fl oz 5 GPA	0.1	195.5 abc	190.5 ab	181.3 bcd
Midac FC + 10-34-0	DIF	13.6 fl oz 5 GPA	0.18	178.4 cd	181.3 abc	173.4 cd
VCP034 + 10-34-0	DIF	5.76 fl oz 5 GPA		188.6 bcd	178.8 abc	165.7 de
Poncho Beta + Midac FC + 10-34-0	Seed DIF	 13.6 fl oz 5 GPA	68 g a.i./ unit seed 0.18	157.3 e	167.3 bc	149.6 ef
Bifender FC + 10-34-0	DIF	7.3 fl oz 5 GPA	0.1	180.9 cd	173.0 abc	145.7 efg
Counter 20G + 10-34-0	B DIF	7.5 lb 5 GPA	1.5	158.6 e	164.1 c	142.5 fg
Poncho Beta + 10-34-0	Seed DIF	 5 GPA	68 g a.i./ unit seed	136.8 f	132.0 d	134.8 fg
Check	---	---	---	212.3 a	177.3 abc	125.9 gh
10-34-0 fertilizer check	DIF	5 GPA	---	173.8 de	173.6 abc	104.5 h
LSD (0.05)				17.23	25.02	22.90

Means within a column sharing a letter are not significantly (P = 0.05) different from each other (Fisher's Protected LSD test).

[a]Carrier for at-plant treatments that included starter fertilizer involved a 3:2 gal. ratio of H_2O to liquid 10-34-0 fertilizer. Output volume was 5 GPA.

[b]Seed = insecticidal seed treatment; B = 5-inch band at planting; 3" TB = 3-inch band over open seed furrow at planting; DIF = dribble in-furrow at planting

[c]Surviving plant stands were counted on 3, 22, and 29 June, 2021 (i.e., 21, 40, and 47 days after planting [DAP], respectively).

These early plant stand counts suggest a few concerns. The first of which is that planting Poncho Beta-treated seed and including 10-34-0 starter fertilizer at planting has at least the potential to negatively impact seedling emergence and/or survival. However, further study should be conducted to confirm or rule out this concern. Secondly, the results of this first stand count indicate that banding Counter 20G at its moderate rate (7.5 lb product/ac) at planting and combining the application with a concurrent (i.e., separate delivery system) application of 10-34-0 starter fertilizer could also delay or reduce sugarbeet seedling emergence.

The highest average surviving plant stand in the trial at 40 DAP was observed in plots treated with Counter 20G at 8.9 lb product per acre (no starter fertilizer); however, the plant stand recorded for that treatment was not statistically greater than the following treatments: 1) Counter 20G at 7.5 lb/ac, no fertilizer; 2) Midac FC + 10-34-0 starter fertilizer + Bifender FC postemergence; 3) Bifender FC plus 10-34-0 [3" T-band or DIF]; 4) Midac + 10-34-0; 5) VCP034 + 10-34-0; 6) untreated check; and 7) the fertilizer-only check. The true untreated check and the fertilizer control did not differ significantly with respect to surviving stand at 40 DAP. The lowest overall plant densities at 40 DAP were recorded in plots planted with Poncho Beta-treated seed when 10-34-0 starter fertilizer was applied DIF at planting. Another concerning result was that plant stands were significantly lower in plots treated with Counter 20G at 7.5 lb/ac plus a concurrent application of 10-34-0 starter fertilizer when compared to similar plots that received Counter 20G at 7.5 lb/ac without starter fertilizer.

The third stand count (i.e., 47 DAP) was carried out on June 29, which should have been after most SBRM larval feeding activity had occurred. As such, this data should be interpreted for treatment impacts on both crop safety and efficacy at protecting plants from mortality resulting from SBRM feeding injury. At this last (47 DAP) count, excellent stands were achieved by using the following treatments, which were not significantly different from each other in respect to surviving plant densities: 1) Counter 20G banded at 7.5 lb product/ac (no fertilizer); 2) Counter 20G banded at 8.9 lb product/ac (no fertilizer); and 3) Midac FC + 10-34-0, applied DIF + Bifender FC applied postemergence. Other treatments that resulted in surviving plant stands at 47 DAP that were significantly greater than the untreated check and the fertilizer-only check included the following: 1) Midac FC + 10-34-0, applied DIF; 2) VCP034 + 10-34-0, applied DIF; and 3) Poncho Beta seed + Midac FC + 10-34-0, applied DIF.

Unfortunately, stand counts in the following treatments were not statistically different from the untreated check at 47DAP, the final stand assessment: 1) Bifender FC at 7.3 fl oz/ac + 10-34-0 starter fertilizer, applied DIF; 2) Counter 20G banded at 7.5 lb product/ac + a DIF application of 10-34-0; and 3) Poncho Beta-treated seed + a DIF application of 10-34-0. Also disappointing was that plots treated with Counter 20G at its moderate labeled rate (7.5 lb/ac) had significantly lower plant densities per 100 ft at the last stand count when a concurrent application of starter fertilizer was included. The addition of starter fertilizer resulted in a 31% stand reduction in that comparison.

Overall, this stand count data suggests that 10-34-0 starter fertilizer itself has potential to reduce or delay sugarbeet seedling emergence, at least under the light-textured soil conditions that characterized this field location. It should also be noted that extremely hot and dry conditions persisted for much of the first few weeks of the 2021 growing season, which could have exacerbated the potential for phytotoxic impacts from the fertilizer on young sugarbeet seedlings.

Results from sugarbeet root maggot feeding injury ratings in this experiment are presented in Table 2. Average root injury ratings in the untreated check (8.33) and fertilizer-only check (8.05) indicated that a very high SBRM infestation was present for the study. All insecticide treatments provided significant reductions in SBRM feeding injury when compared to that recorded for the untreated check plots, but the lowest root injury ratings in the trial were recorded in plots that received a planting-time banded application of Counter 20G at the lower, 7.5-lb rate when starter fertilizer was excluded.

Table 2. *Larval feeding injury ratings* from an evaluation of Midac® and Bifender® insecticides for sugarbeet root maggot control, St. Thomas, ND, 2021

Treatment/form.[a]	Placement[b]	Rate (product/ac)	Rate (lb a.i./ac)	Root injury (0-9)
Counter 20G	B	7.5 lb	1.5	5.13 f
Counter 20G	B	8.9 lb	1.8	5.25 ef
Poncho Beta + Midac FC + 10-34-0	Seed DIF	 13.6 fl oz 5 GPA	68 g a.i./ unit seed 0.18	5.30 ef
Counter 20G + 10-34-0	B DIF	7.5 lb 5 GPA	1.5	5.48 def
Midac FC + 10-34-0 + Bifender FC	DIF 1 d Pre-peak Broadcast	13.6 fl oz 5 GPA 7.3 fl oz	0.18 0.1	5.55 def
Poncho Beta + 10-34-0	Seed DIF	 5 GPA	68 g a.i./ unit seed	5.88 de
Bifender FC + 10-34-0	3” TB	7.3 fl oz 5 GPA	0.1	6.18 cd
Midac FC + 10-34-0	DIF	13.6 fl oz 5 GPA	0.18	6.68 bc
VCP034 + 10-34-0	DIF	5.76 fl oz 5 GPA		6.75 bc
Bifender FC + 10-34-0	DIF	7.3 fl oz 5 GPA	0.1	7.13 b
10-34-0 fertilizer check	DIF	5 GPA	---	8.05 a
Check	---	---	---	8.33 a
LSD (0.05)				0.745

Means within a column sharing a letter are not significantly (P = 0.05) different from each other (Fisher’s Protected LSD test).

[a]Carrier for at-plant treatments that included starter fertilizer involved a 3:2 gal. ratio of H_2O to liquid 10-34-0 fertilizer. Output volume was 5 GPA.

[b]Seed = insecticidal seed treatment; B = 5-inch band at planting; 3” TB = 3-inch band over open seed furrow at planting; DIF = dribble in-furrow at planting

Other treatments that provided good levels of protection from SBRM feeding injury included the following (listed in descending order of performance): 1) Counter 20G banded at 8.9 lb product/ac (no fertilizer); 2) Poncho Beta-treated seed + a tank mixture of Midac FC + 10-34-0 starter fertilizer, applied DIF; 3) Counter 20G banded at 7.5 lb product/ac + a concurrent application of 10-34-0; and 4) Midac FC + 10-34-0 starter fertilizer + postemergence Bifender FC (1d before peak fly activity).

Relatively poor performance in relation to root protection from SBRM feeding injury was observed with Bifender FC, Midac FC, and VCP034; however, Bifender FC performed significantly better (i.e., lower SBRM root injury) when applied as a 3" T-band as compared to the DIF application. Also, despite the findings that stand counts appearing to be negatively impacted by including 10-34-0 starter fertilizer, the results from root ratings suggest that combining at-plant applications of Counter 20G, Poncho Beta seed treatment, or Midac FC with starter fertilizer are not likely to reduce efficacy of the insecticides at protecting sugarbeet roots from SBRM feeding injury.

Yield data from this experiment are shown in Table 3. The top-yielding treatment in the trial, with regard to both recoverable sucrose yield and root tonnage, was the combination of Poncho Beta-treated seed planted with a DIF-placed tank mixture of Midac FC plus 10-34-0 starter fertilizer. Combining these two pest management tools (i.e., Poncho Beta-treated seed and Midac FC) increased gross economic return by $104/ac over Poncho Beta alone and by $230/ac over Midac alone, which suggests that this combination should be considered for use in fields where there is substantial risk of high SBRM infestations. Other treatments that produced similar recoverable sucrose yield and root tonnage values that were not statistically different from the top treatment included the following: 1) Counter 20G banded at 8.9 lb/ac (no fertilizer); 2) Poncho Beta + 10-34-0 starter fertilizer; 3) Counter 20G banded at 8.9 lb/ac (no fertilizer); and 4) the T-banded application of Bifender tank mixed with starter fertilizer.

Table 3. *Yield parameters* from an evaluation of Midac® and Bifender® insecticides for sugarbeet root maggot control, St. Thomas, ND, 2021

Treatment/form.[a]	Placement[b]	Rate (product/ac)	Rate (lb a.i./ac)	Sucrose yield (lb/ac)	Root yield (T/ac)	Sucrose (%)	Gross return ($/ac)
Poncho Beta + Midac FC + 10-34-0	Seed DIF	 13.6 fl oz 5 GPA	68 g a.i./ unit seed 0.18	5,616 a	20.1 a	15.31 ab	822
Counter 20G	B	8.9 lb	1.8	5,276 ab	19.0 ab	15.25 ab	769
Poncho Beta + 10-34-0	Seed DIF	 5 GPA	68 g a.i./ unit seed	5,183 abc	19.4 a	14.81 b-e	718
Counter 20G	B	7.5 lb	1.5	5,096 a-d	18.1 abc	15.42 a	751
Bifender FC + 10-34-0	3" TB	7.3 fl oz 5 GPA	0.1	4,965 a-d	18.3 abc	14.93 abc	700
Counter 20G + 10-34-0	B DIF	7.5 lb 5 GPA	1.5	4,732 b-e	17.4 abc	15.02 abc	670
Midac FC + 10-34-0 + Bifender FC	DIF 1 d Pre-peak Broadcast	13.6 fl oz 5 GPA 7.3 fl oz	0.18 0.1	4,407 cde	16.4 bcd	14.90 a-d	616
Midac FC + 10-34-0	DIF	13.6 fl oz 5 GPA	0.18	4,319 def	16.3 bcd	14.62 c-f	592
VCP034 + 10-34-0	DIF	5.76 fl oz 5 GPA		4,088 ef	15.9 cd	14.29 ef	537
Check	---	---	---	3,555 fg	13.7 de	14.35 def	469
Bifender FC + 10-34-0	DIF	7.3 fl oz 5 GPA	0.1	3,223 g	12.6 e	14.19 f	416
10-34-0 fertilizer check	DIF	5 GPA		3,025 g	11.7 e	14.25 ef	398
LSD (0.05)				784.0	2.75	0.563	

Means within a column sharing a letter are not significantly (P = 0.05) different from each other (Fisher's Protected LSD test).

[a]Carrier for at-plant treatments that included starter fertilizer involved a 3:2 gal. ratio of H_2O to liquid 10-34-0 fertilizer. Output volume was 5 GPA.

[b]Seed = insecticidal seed treatment; B = 5-inch band at planting; 3" TB = 3-inch band over open seed furrow at planting; DIF = dribble in-furrow at planting

Although stand counts demonstrated a negative impact from applying 10-34-0 starter fertilizer concurrently with Counter 20G, the fertilizer, and perhaps larger beet roots due to reduced plant populations in fertilizer-treated Counter plots, appeared to minimize negative impacts on resultant yield parameters. However, despite the absence of a significant difference between Counter 20G alone and Counter 20G plus starter fertilizer, Counter-treated plots that received the concurrent application of starter fertilizer generated $81/ac in gross revenue when compared to those where the fertilizer was excluded.

Similar to the results from root injury ratings in this trial, yield comparisons indicated that marginal to relatively poor performance was achieved by DIF applications of Midac FC, VCP034, and Bifender FC. However, one very positive and definitive result from this trial was that placement (i.e., 3" T-band vs. DIF) had a significant impact on performance of Bifender FC. The T-banded placement of Bifender was superior to DIF in regard to surviving plant stands, root protection from SBRM feeding injury, as well as recoverable sucrose yield and root tonnage. Additionally, plots treated with the T-banded application of Bifender resulted in $284 more economic return than those that received the product via DIF placement. Although this is a very encouraging finding, capitalizing on it would require producers to modify their sugarbeet planters by equipping them with conventional nozzles instead of the commonly used dribble-in-furrow delivery systems.

Overall results of this trial suggest that, for growers intending on applying Counter 20G at planting and also including a concurrent application of 10-34-0 starter fertilizer, it is advisable to at least dilute the fertilizer to the 3:2 gallon (i.e., 3 gallons of fertilizer to 2 gallons of water) ratio used in this study, or even further dilute it, if choosing to use the full 8.9-lb rate of Counter. Results also suggest that combining Poncho Beta-treated seed with an application of Midac FC plus 10-34-0 starter fertilizer can improve SBRM control and resulting yield and gross revenue over that of either Poncho Beta or Midac FC alone.

It should be noted that data from previous NDSU research suggests that Midac FC performs at a comparable level to that of the moderate rate of Counter 20G (i.e., 7.5 lb product/ac). Thus, if planting-time insecticide protection is limited to Midac FC, the grower should expect the need to add a postemergence rescue insecticide application to augment SBRM control, especially in areas of moderate to high risk of economically damaging root maggot populations.

Finally, it should be noted that most of the treatments tested in this trial need further testing to determine the validity and repeatability of these results. This is especially so with regard to the safety of combining Counter 20G applications with concurrent starter fertilizer applications.

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