CONCURRENT AND TANK-MIXED INSECTICIDE AND FUNGICIDE APPLICATIONS IN SUGARBEET: IMPACTS ON ROOT MAGGOT CONTROL AND YIELD

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Introduction:

Red River Valley (RRV) sugarbeet producers, especially those in central and northern portions of the growing area, can realize significant economic benefits from insecticide, fungicide, and starter fertilizer applications. Insecticide protection is needed by many RRV producers to protect against losses associated with the sugarbeet root maggot (SBRM), *Tetanops myopaeformis* (Röder), a perennial pest of sugarbeet in the RRV. Producers typically manage this pest through prophylactic insecticide application during sugarbeet planting. At-plant insecticide options include granular or sprayable liquid formulations, or the use of insecticide-treated seed. In situations where high SBRM fly activity and associated larval feeding pressure are expected, most producers complement their at-plant protection with a postemergence insecticide, which can involve either granular or sprayable liquid formulations.

Fungicides are often needed to manage soil-borne root diseases such as Rhizoctonia damping off, as well as Rhizoctonia crown and root rot, which are all caused by the pathogen *Rhizoctonia solani* Kühn. Similar to the insecticides used for SBRM management, fungicides targeting Rhizoctonia management in sugarbeet also can be delivered as planting-time and postemergence applications. Starter fertilizer applications are also commonly used by RRV sugarbeet producers. If demonstrated to be safe for the crop, consolidating insecticide, fungicide, and/or starter fertilizer treatments into either tank-mixed or independent, but concurrent, delivery systems during planting or postemergence spray operations would provide time savings and significant application-associated input costs.

This experiment was carried out to evaluate the impact of such multicomponent application systems on sugarbeet root maggot control. A secondary objective was to monitor for any potential symptoms of phytotoxic effects of the treatment combinations, including impacts on plant emergence and survival. Several treatment combinations, based on the following application groupings, were evaluated:

1) Counter 20G insecticide at planting time with a concurrent (i.e., at same time through a separate application system) application of 10-34-0 starter fertilizer;

2) Counter 20G at planting time with a concurrently applied tank mixture of 10-34-0 starter fertilizer plus AZteroid (i.e., azoxystrobin) fungicide;

3) Yuma 4E insecticide applied postemergence in a tank mixture with Quadris (i.e., azoxystrobin) fungicide; and

4) Thimet 20G insecticide applied postemergence with a concurrent application of azoxystrobin (i.e., Quadris) fungicide.

Materials and Methods:

This experiment was planted on May 19, 2020 in a commercial sugarbeet field site near St. Thomas in rural Pembina County, ND. Betaseed 8524 glyphosate-resistant seed was used for all treatments. 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 was used to plant the trial. Plots were six rows (22-inch spacing) wide with the four centermost rows treated. The outer "guard" row on each side of the plot served as an untreated buffer. 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. AZteroid was used as the azoxystrobin-based fungicide for planting-time treatment combinations, and Quadris was chosen as the postemergence version of an azoxystrobin-based fungicide. These selections reflect the most common uses of azoxystrobin for respective planting-time and postemergence fungicide applications to manage root diseases in the Red River Valley growing area.

Planting-time insecticide applications. 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.

Planting-time liquid spray applications included both T-band and dribble in-furrow (DIF). T-band placement involved delivering spray system output in a 3-inch swath over each open seed furrow by using a planter-mounted, CO_2-propelled spray system equipped with TeeJet™ 450067E nozzles and calibrated to apply a finished spray volume output of 5 GPA. Dribble in-furrow applications were made by orienting a microtube (1/4" outside diam.) directly into the open seed furrow. Inline Teejet™ No. 18 orifice plates were used to stabilize the output rate of the spray solutions from the microtubes.

Postemergence insecticide applications. Additive postemergence insecticides applied in this trial included Yuma 4E (a generic chlorpyrifos formulation, similar to Lorsban 4E) and Thimet 20G, and both materials were applied on June 17, which was just one day before peak SBRM fly activity. That timing, is not recommended for applications of Yuma (recommended for 2-5 days pre-peak), and even more so, Thimet 20G (recommended for 5-14 days pre-peak); however, an equipment failure and long periods of unfavorable weather prevented more timely applications of treatments that included those products.

Liquid insecticide solutions were delivered with a tractor-mounted CO_2-propelled spray system equipped with TeeJet™ 110015VS AIXR nozzles, and the system was calibrated to deliver a finished output volume of 10 GPA. Postemergence granular output rates were regulated by using a SmartBox™ system mounted on a tractor-drawn four-row toolbar, and placement of insecticide in 4-inch bands was achieved by using Kinze™ row banders. Granules were incorporated by using two pairs of metal rotary tines that straddled each row. A set of tines was positioned ahead of each bander, and a second pair was mounted behind the granular drop zone.

Plant Stand Counts: To measure relative safety of the various treatment combinations in this trial, plant density (i.e., number of surviving plants per unit row length) assessments were conducted at 37, 49, and 62 days after planting (DAP). This involved counting all surviving plants within each 35-ft plot row, and converting the counts to the commonly understood index of plants per 100 linear row feet.

Root injury ratings: Sugarbeet root maggot feeding injury was assessed in this experiment on July 27, 2020. 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: Treatment performance was also compared on the basis of sugarbeet yield parameters. Plots were harvested on September 23. 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 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). Treatment means were compared by using Fisher's protected least significant difference (LSD) test at a 0.05 level of significance.

Results and Discussion:

Results from stand count assessments are presented in Table 1. There were no significant differences among treatments during the first stand count (37 DAP), suggesting that there were no negative or positive impacts from any of the treatments on seedling emergence or survival. Although there were occasional statistically significant differences between treatments at both 49 and 62 DAP, none appeared to be the result of negative interactions from either combining an at-plant application of Counter 20G with either starter fertilizer or AZteroid fungicide, or from combining postemergence applications of Yuma 4E with Quadris fungicide. There also were no significant reductions in plant stands in relation to insecticide application rate for any of the at-plant or postemergence treatment combinations.

Sugarbeet root maggot feeding injury results from this two-year trial are shown in Table 2. This data should be interpreted with the aforementioned fact that an equipment failure and unfavorable weather conditions prevented the applications of Yuma 4E and Thimet 20G at preplanned timings in relation to peak SBRM fly activity. As such, the performance levels of treatments including those products could have been negatively affected.

Table 1. *Plant stand counts* from an evaluation of concurrently applied and tank-mixed combinations of azoxystrobin fungicides with sugarbeet root maggot-targeted insecticides, St. Thomas, ND, 2020

Treatment/form.[a]	Placement[b]	Rate (product/ac)	Rate (lb a.i./ac)	Stand count[c] (plants / 100 ft)		
				37 DAP	49 DAP	62 DAP
Counter 20G + Thimet 20G	B 4" Post B, 1 d Pre-peak	8.9 lb 7 lb	1.8 1.4	211.4 a	221.8 a	213.6 a
Counter 20G	B	7.5 lb	1.5	184.6 a	212.1 ab	210.9 a
Counter 20G + Yuma 4E + Quadris	B 10" Post B, 1 d Pre-peak	8.9 lb 2 pt 10 fl oz	1.8 1.0 0.17	187.0 a	174.3 cd	205.5 ab
Counter 20G + Yuma 4E + Quadris	B 10" Post B, 1 d Pre-peak	8.9 lb 1 pt 10 fl oz	1.8 0.5 0.17	189.1 a	200.9 abc	200.7 ab
Counter 20G + Yuma 4E	B 10" Post B, 1 d Pre-peak	7.5 lb 2 pt	1.5 1.0	185.7 a	205.0 abc	199.1 ab
Counter 20G + Yuma 4E + Quadris	B 10" Post B, 1 d Pre-peak	7.5 lb 2 pt 10 fl oz	1.5 1.0 0.17	176.4 a	119.1 abc	198.6 ab
Counter 20G + Thimet 20G + Quadris	B 4" Post B, 1 d Pre-peak 10" Post B, 1 d Pre-peak	8.9 lb 7 lb 10 fl oz	1.8 1.4 0.17	184.5 a	208.2 abc	196.1 abc
Counter 20G + 10-34-0	B DIF	7.5 lb 5 GPA	1.5	187.1 a	192.1 a-d	191.1 abc
Counter 20G + 10-34-0	B DIF	8.9 lb 5 GPA	1.8	180.5 a	184.5 a-d	183.9 bc
Counter 20G + AZteroid FC + 10-34-0	B DIF	8.9 lb 5.7 fl oz 5 GPA	1.8 0.15	175.9 a	182.3 bcd	182.5 bc
Counter 20G + AZteroid FC + 10-34-0	B DIF	7.5 lb 5.7 fl oz 5 GPA	1.5 0.15	163.4 a	186.6 a-d	182.3 bc
Counter 20G	B	8.9 lb	1.8	190.9 a	183.8 bcd	174.3 c
Fertilizer check	DIF	5 GPA		168.8 a	155.7 d	144.6 d
Check	---	----	---	192.5 a	160.4 d	133.4 d
LSD (0.05)				NS	37.40	24.16

Means within a column sharing a letter are not significantly (P = 0.05) different from each other (Fisher's Protected LSD test).
[a]At-plant sprays were delivered in a 10-34-0 starter fertilizer/water carrier (3:2 gal. H_2O to fertilizer) at an output volume of 5 GPA.
[b]B = 5-inch at-plant band; Post B = postemergence band (i.e., 4-inch width for granular products; 10-inch width for liquid formulations); DIF = dribble in-furrow
[c]Surviving plant stands were counted on 25 June, and on 7 and 20 July, 2020 (i.e., 37, 49, and 62 days after planting [DAP], respectively).

The average SBRM feeding injury sustained in the true untreated check and the fertilizer-only check plots (7.63 and 6.45, respectively, on the 0 to 9 scale of Campbell et al. [2000]) indicated the presence of a relatively high larval infestation for the experiment. All insecticide-treated entries in the trial provided significant reductions in SBRM feeding injury when compared to the untreated check. The lowest level of SBRM feeding injury (i.e., the highest level of protection) was observed in plots that received the combination of a planting-time application of Counter 20G at its moderate labeled rate (7.5 lb product/ac) plus a tank-mixed postemergence combination of Yuma 4E (2 pts/ac) plus Quadris fungicide; however, that entry was not statistically superior to any of the dual (i.e., planting-time plus postemergence) insecticide entries in the trial. Root protection from SBRM feeding injury was not significantly impaired by applying starter fertilizer and/or AZteroid fungicide at the same time as banded applications of Counter 20G at planting time. Similarly, there were no significant reductions in SBRM control when Quadris was applied concurrently with Thimet 20G or when it was tank mixed with Yuma 4E, irrespective of the rate at which the insecticides were applied.

Table 2. ***Larval feeding injury*** **from an evaluation of concurrently applied and tank-mixed combinations of azoxystrobin fungicides with sugarbeet root maggot-targeted insecticides, St. Thomas, ND, 2020**

Treatment/form.[a]	Placement[b]	Rate (product/ac)	Rate (lb a.i./ac)	Root injury (0-9)
Counter 20G + Yuma 4E + Quadris	B 10" Post B, 1 d Pre-peak	7.5 lb 2 pt 10 fl oz	1.5 1.0 0.17	2.55 e
Counter 20G + Yuma 4E + Quadris	B 10" Post B, 1 d Pre-peak	8.9 lb 2 pt 10 fl oz	1.8 1.0 0.17	2.88 e
Counter 20G + Thimet 20G + Quadris	B 4" Post B, 1 d Pre-peak 10" Post B, 1 d Pre-peak	8.9 lb 7 lb 10 fl oz	1.8 1.4 0.17	3.20 de
Counter 20G + Yuma 4E	B 10" Post B, 1 d Pre-peak	7.5 lb 2 pt	1.5 1.0	3.20 de
Counter 20G + Yuma 4E + Quadris	B 10" Post B, 1 d Pre-peak	8.9 lb 1 pt 10 fl oz	1.8 0.5 0.17	3.33 cde
Counter 20G + Thimet 20G	B 4" Post B, 1 d Pre-peak	8.9 lb 7 lb	1.8 1.4	3.63 cde
Counter 20G + 10-34-0	B DIF	7.5 lb 5 GPA	1.5	4.45 bcd
Counter 20G	B	7.5 lb	1.5	4.63 bc
Counter 20G + 10-34-0	B DIF	8.9 lb 5 GPA	1.8	4.63 bc
Counter 20G + AZteroid FC + 10-34-0	B DIF	8.9 lb 5.7 fl oz 5 GPA	1.8 0.15	4.63 bc
Counter 20G + AZteroid FC + 10-34-0	B DIF	7.5 lb 5.7 fl oz 5 GPA	1.5 0.15	4.63 bc
Counter 20G	B	8.9 lb	1.8	4.98 b
Fertilizer check	DIF	5 GPA		6.45 a
Check	-----	----	-----	7.63 a
LSD (0.05)				1.350

Means within a column sharing a letter are not significantly (*P* = 0.05) different from each other (Fisher's Protected LSD test).
[a]At-plant sprays were delivered in a 10-34-0 starter fertilizer/water carrier (3:2 gal. H_2O to fertilizer) at an output volume of 5 GPA.
[b]B = 5-inch at-plant band; Post B = postemergence band (i.e., 4-inch width for granular products; 10-inch width for liquid formulations); DIF = dribble in-furrow

Yield data from this experiment are presented in Table 3. As noted with SBRM feeding injury results, the interpretation of yield results from this trial should be interpreted carefully and with the understanding that postemergence applications of Yuma 4E and Thimet 20G were both applied later than planned. Overall performance patterns indicated that treatment combinations including dual (planting-time plus postemergence) insecticide applications provided greater recoverable sucrose and root yields, and higher gross economic returns.

The treatment combination comprised of Counter 20G at its high labeled rate (8.9 lb product/ac) plus a postemergence tank mixture of Yuma 4E (high labeled rate of 2 pts product/ac) and Quadris fungicide at its recommended rate (10 fl oz product/ac) produced greatest recoverable sucrose yield, root tonnage, and gross revenue in this trial. However, a similar treatment, only differing by a reduced rate of Yuma (1 pt/ac), produced comparable sucrose and root yields, and a nearly identical gross economic return as when the Yuma component was applied at its full 2-pt labeled rate.

Although not statistically significant, percent sucrose content and resulting recoverable sucrose yield were numerically reduced by tank mixing Quadris fungicide with the full labeled rate (2 pts product/ac) of Yuma 4E in plots initially treated at planting with Counter at its moderate labeled rate (7.5 lb/ac). The resulting revenue reduction by including Quadris with 2 pts of Yuma was $120.

Table 3. Impacts of concurrently applied and tank-mixed combinations of azoxystrobin fungicides and sugarbeet root maggot-targeted insecticides on *yield parameters*, St. Thomas, ND, 2020

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)
Counter 20G + Yuma 4E + Quadris	B 10" Post B, 1 d Pre-peak	8.9 lb 2 pt 10 fl oz	1.8 1.0 0.17	10,394 a	33.8 a	17.80 a	1,342
Counter 20G + Yuma 4E + Quadris	B 10" Post B, 1 d Pre-peak	8.9 lb 1 pt 10 fl oz	1.8 0.5 0.17	10,218 a	32.8 ab	17.00 a	1,341
Counter 20G + Yuma 4E	B 10" Post B, 1 d Pre-peak	7.5 lb 2 pt	1.5 1.0	10,009 a	31.8 abc	16.93 a	1,331
Counter 20G + Yuma 4E + Quadris	B 10" Post B, 1 d Pre-peak	7.5 lb 2 pt 10 fl oz	1.5 1.0 0.17	9,683 ab	32.1 ab	16.49 a	1,211
Counter 20G + Thimet 20G	B 4" Post B, 1 d Pre-peak	8.9 lb 7 lb	1.8 1.4	9,397 ab	29.2 bcd	17.33 a	1,286
Counter 20G + Thimet 20G + Quadris	B 4" Post B, 1 d Pre-peak 10" Post B, 1 d Pre-peak	8.9 lb 7 lb 10 fl oz	1.8 1.4 0.17	9,247 abc	27.8 cde	16.67 a	1,320
Counter 20G + AZteroid FC + 10-34-0	B DIF	7.5 lb 5.7 fl oz 5 GPA	1.5 0.15	8,988 a-d	27.3 de	17.63 a	1,266
Counter 20G + 10-34-0	B DIF	7.5 lb 5 GPA	1.5	8,506 bcd	27.3 de	16.91 a	1,116
Counter 20G + AZteroid FC + 10-34-0	B DIF	8.9 lb 5.7 fl oz 5 GPA	1.8 0.15	8,473 bcd	25.9 def	17.60 a	1,187
Counter 20G	B	8.9 lb	1.8	8,429 bcd	25.9 def	17.50 a	1,171
Counter 20G + 10-34-0	B DIF	8.9 lb 5 GPA	1.8	7,964 de	24.9 ef	17.48 a	1,082
Counter 20G	B	7.5 lb	1.5	7,639 de	24.1 ef	17.10 a	1,025
Fertilizer check	DIF	5 GPA		6,986 e	21.8 f	17.34 a	951
Check	-----	----	-----	6,673 e	22.3 f	16.40 a	824
LSD (0.05)				1,408.6	4.10	NS	

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

[a]At-plant sprays were delivered in a 10-34-0 starter fertilizer/water carrier (3:2 gal. H_2O to fertilizer) at an output volume of 5 GPA.

[b]B = 5-inch at-plant band; Post B = postemergence band (i.e., 4-inch width for granular products; 10-inch width for liquid formulations); DIF = dribble in-furrow

In plots that received the planting-time combination of a banded application of Counter 20G at 7.5 lb product per acre plus a concurrently applied (i.e., dribbled in-furrow) application of 10-34-0 starter fertilizer, the inclusion of the fertilizer resulted in numerical, but not statistically significant, increases in both recoverable sucrose yield and root tonnage per acre. Additionally, in plots that received the same (7.5 lb) rate of Counter, adding AZteriod fungicide to the planting-time fertilizer application resulted in even larger, albeit not statistically significant, increases in both recoverable sucrose and root yield. Plots treated with that combination (i.e., Counter 20G at 7.5 lb/ac plus a tank mixture of 10-34-0 starter fertilizer and AZteroid fungicide) generated $150/ac more revenue than similar plots that excluded AZteroid, and $241 more revenue than plots that did not include fungicide or fertilizer. However, when Counter was applied at its high labeled rate (8.9 lb product/ac), slight, non-significant reductions in recoverable sucrose yield, root tonnage, and gross revenue were observed when 10-34-0 starter fertilizer was applied in furrow ahead of the insecticide bands at planting time. The triple-component planting-time combination of Counter, AZteroid, and 10-34-0 starter fertilizer produced greater recoverable sucrose, root yield, and gross revenue when Counter was applied at the moderate rate of 7.5 lb product/ac. That treatment program generated $79 more revenue than when Counter was applied at 8.9 lb/ac in combination with a concurrent application of AZteroid with starter fertilizer.

The overall findings of this experiment suggest that combining 10-34-0 starter fertilizer and/or azoxystrobin-based fungicide applications with SBRM-targeted insecticides, through either tank-mixed or concurrent delivery systems, is not likely to result in reduced root maggot control or negative impacts on sugarbeet yield or quality. However, two concerning observations included the following: 1) applying 10-34-0 starter fertilizer into the seed furrow during planting while concurrently applying Counter 20G at its high rate (8.9 lb product/ac) rate resulted in a slight (not statistically significant) yield reductions and reduced revenue by $89/ac when compared to similar plots that did not include the fertilizer application; and 2) in plots initially protected by the lower (7.5-lb) rate of Counter 20G, a gross revenue loss of $120 occurred when Quadris fungicide was combined with a full labeled rate of Yuma 4E at postemergence. These concerns strongly suggest further study of these combinations.
It also should be noted that this trial was conducted in an environment that included high SBRM feeding pressure. As such, the net impacts of the treatment combinations on plant health (i.e., excluding SBRM control) cannot be accurately measured. Therefore, this research should be continued under both pest-free and SBRM-infested scenarios to more fully characterize the safety as well as SBRM control efficacy of these treatment combinations.

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