**2024 FINAL REPORT (project ogoing)**

PROJECT TITLE: Investigating the Efficacy of Insecticidal Seed Treatments in Bt and Non-Bt Corn for Managing Corn Rootworm Complex (Year 1)
PROJECT NUMBER: 6125-24DD
REPORTING PERIOD: 08/01/2023-02/28/2025
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1.) PROJECT ACTIVITIES COMPLETED DURING THE REPORTING PERIOD. (*Describe project progress specific to goals, objectives, and deliverables identified in the project workplan.*)

<u>Field assays to determine the efficacy of seed treatments for control of rootworms in Minnesota:</u> The objective of this study is to evaluate the efficacy of high-rate insecticidal seed treatments (ISTs) such as thiamethoxam, clothianidin, and chlorantraniliprole, and their interactions with Bt traits for controlling corn rootworms in Minnesota. During the 2024 growing season, two independent field trials were successfully conducted at two University of Minnesota Research and Outreach Centers (ROCs): the Southwest Research and Outreach Center at Lamberton (SWROC) and the Rosemount Research and Outreach Center at Rosemount (RROC). A total of 16 treatment groups were included at each location, comprising four corn hybrids and four insecticide treatments. The four corn hybrids included: a non-Bt corn hybrid (VT2P) , a SmartStax Bt corn hybrid containing Cry3Bb1 and Cry34/35Ab1 Bt proteins effective against rootworms (SSX), a VT4Pro Bt corn hybrid with Cry3Bb1, and DvSnf7 dsRNA for targeting rootworms (VT4Pro), and a SmartStax Pro Bt corn hybrid with Cry3Bb1, Cry34/35Ab1 and DvSnf7 dsRNA for targeting rootworms (SSPro). The four insecticide treatments contained: clothianidin seed treatment at 1.25 mg/seed, thiamethoxam at 1.25 mg/seed, Chlorantraniliprole at 0.75 mg/seed, and untreated seed. Experimental data from both ROCs has been collected and analyzed, covering stand counts during the V2-V3 stages, the percentage of lodged plants, root node injury during the R1 stage, and the grain yields.

In RROC, stand count data revealed an average of 27,563 corn plants per acre, with variations among seed treatments and Bt traits (Figure 1). Root injury, assessed using Iowa State University's 0-3 Node Injury Scale, ranged from 0.96 to 1.6 for non-Bt RW corn hybrids (VT2P) across different insecticide seed treatments (Figure 2). Additionally, the percentage of lodged plants in non-Bt RW corn ranged from 4.2% to 34.7% (Figure 3). These results suggest that rootworm pressure was very high at the tested location. However, no significant differences were detected in the percentage of lodged plants and root injury among the non-Bt RW corn treated with clothianidin (1.25 mg/seed), thiamethoxam (1.25 mg/seed), chlorantraniliprole (0.75 mg/seed), or untreated seed. This suggests that the efficacy of these insecticide seed treatments is minimal under high rootworm pressure. In contrast, all Bt corn hybrids (SSX, SSXPro, and VT4Pro) provided excellent control against corn rootworm larvae, indicating that the field populations remain susceptible to these Bt traits. The percentage of lodged plants and root injury for these Bt hybrids ranged from 0.0% to 0.6% and 0 to 0.25, respectively. Additionally, no differences were observed among the different insecticide seed treatments within any single Bt trait, suggesting that seed treatments do not add significant value for rootworm control when Bt traits are still effective. Finally, the yield data showed no statistically significant difference was observed among all the treatments (Figure 4). However, on the non-Bt RW corn, seed treatments of clothianidin (1.25 mg/seed), thiamethoxam (1.25 mg/seed), chlorantraniliprole (0.75 mg/seed) produced numerically higher yields compared to untreated seed (Figure 4). Additionally, all Bt corn hybrids provided better yield compared to non-Bt RW corn, regardless of whether it was treated or untreated, which suggested again that additional seed treatments do not add significant yield for rootworm control when insects are still susceptible to Bt traits.

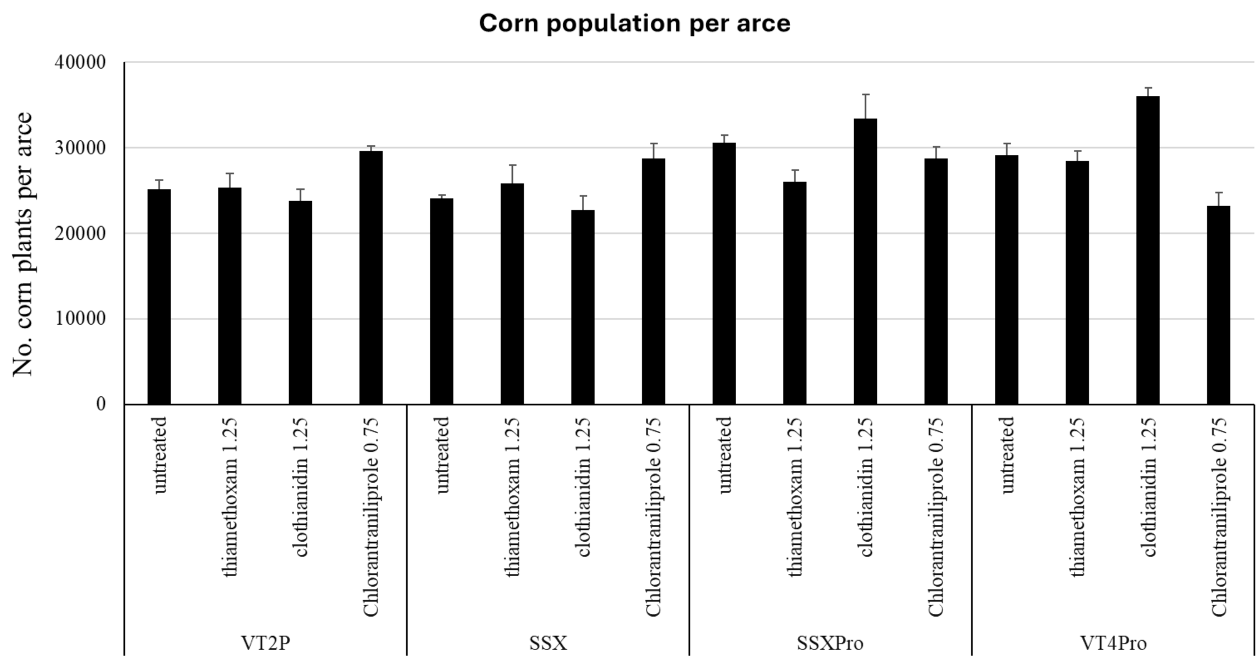


**Figure 1.** Estimated number of corn plants per acre based on the stand count in the field trials in RROC in 2024. VT2P: a non-Bt corn hybrid, SSX: a SmartStax Bt corn hybrid containing Cry3Bb1 and Cry34/35Ab1 Bt proteins effective against rootworms, VT4Pro: a VT4Pro Bt corn hybrid with Cry3Bb1, and DvSnf7 dsRNA for targeting rootworms, and SSPro: a SmartStax Pro Bt corn hybrid with Cry3Bb1, Cry34/35Ab1 and DvSnf7 dsRNA for targeting rootworms. Clothianidin 1.25: seed treatment at 1.25 mg/seed, thiamethoxam 1.25: seed treatment at 1.25 mg/seed, Chlorantraniliprole 0.75: seed treatment at 0.75 mg/seed, and untreated seed.


**Figure 2.** Corn root injury based on the Iowa State University's 0-3 Node Injury Scale in the field trials in RROC in 2024. VT2P: a non-Bt corn hybrid, SSX: a SmartStax Bt corn hybrid containing Cry3Bb1 and Cry34/35Ab1 Bt proteins effective against rootworms, VT4Pro: a VT4Pro Bt corn hybrid with Cry3Bb1, and DvSnf7 dsRNA for targeting rootworms, and SSPro: a SmartStax Pro Bt corn hybrid with Cry3Bb1, Cry34/35Ab1 and DvSnf7 dsRNA for targeting rootworms. Clothianidin 1.25: seed treatment at 1.25 mg/seed, thiamethoxam 1.25: seed treatment at 1.25 mg/seed, Chlorantraniliprole 0.75: seed treatment at 0.75 mg/seed, and untreated seed. NS means no significant statistical differences. * Indicates significant statistical differences.

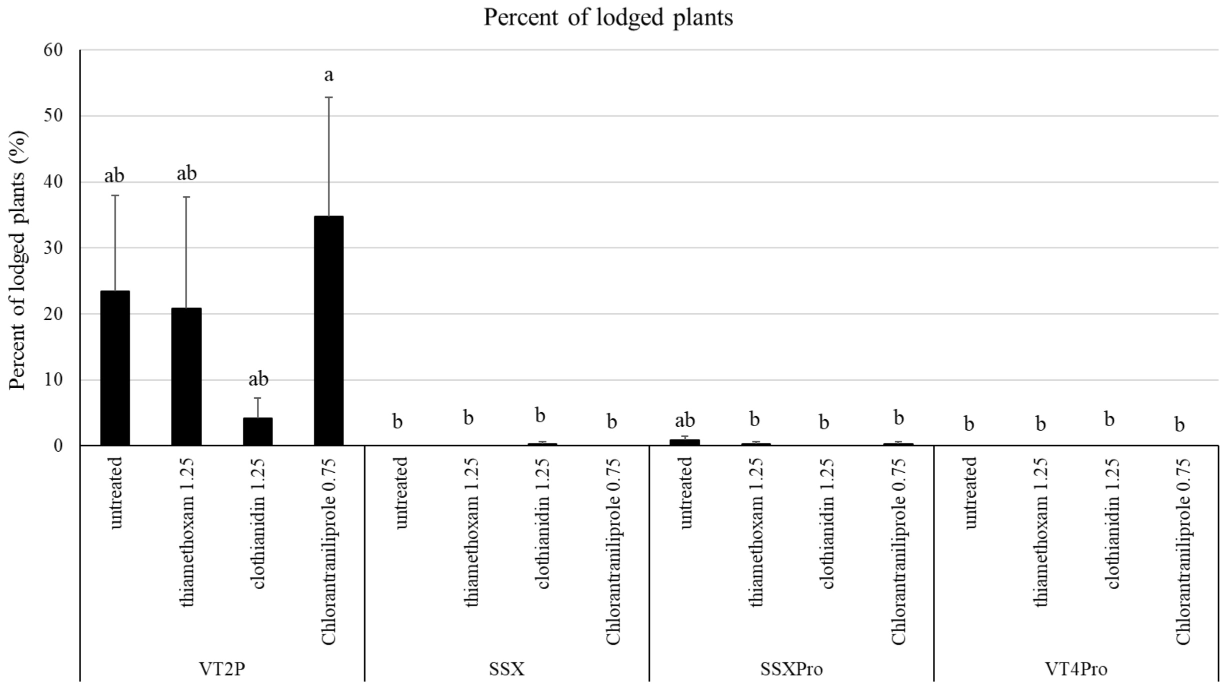


**Figure 3.** Percentage of lodged plants due to root injury from corn rootworm larvae in the field trials in RROC in 2024. VT2P: a non-Bt corn hybrid, SSX: a SmartStax Bt corn hybrid containing Cry3Bb1 and Cry34/35Ab1 Bt proteins effective against rootworms, VT4Pro: a VT4Pro Bt corn hybrid with Cry3Bb1, and DvSnf7 dsRNA for targeting rootworms, and SSPro: a SmartStax Pro Bt corn hybrid with Cry3Bb1, Cry34/35Ab1 and DvSnf7 dsRNA for targeting rootworms. Clothianidin 1.25: seed treatment at 1.25 mg/seed, thiamethoxam 1.25: seed treatment at 1.25 mg/seed, Chlorantraniliprole 0.75: seed treatment at 0.75 mg/seed, and untreated seed. Treatment means with the same letter indicate no significant statistical differences.

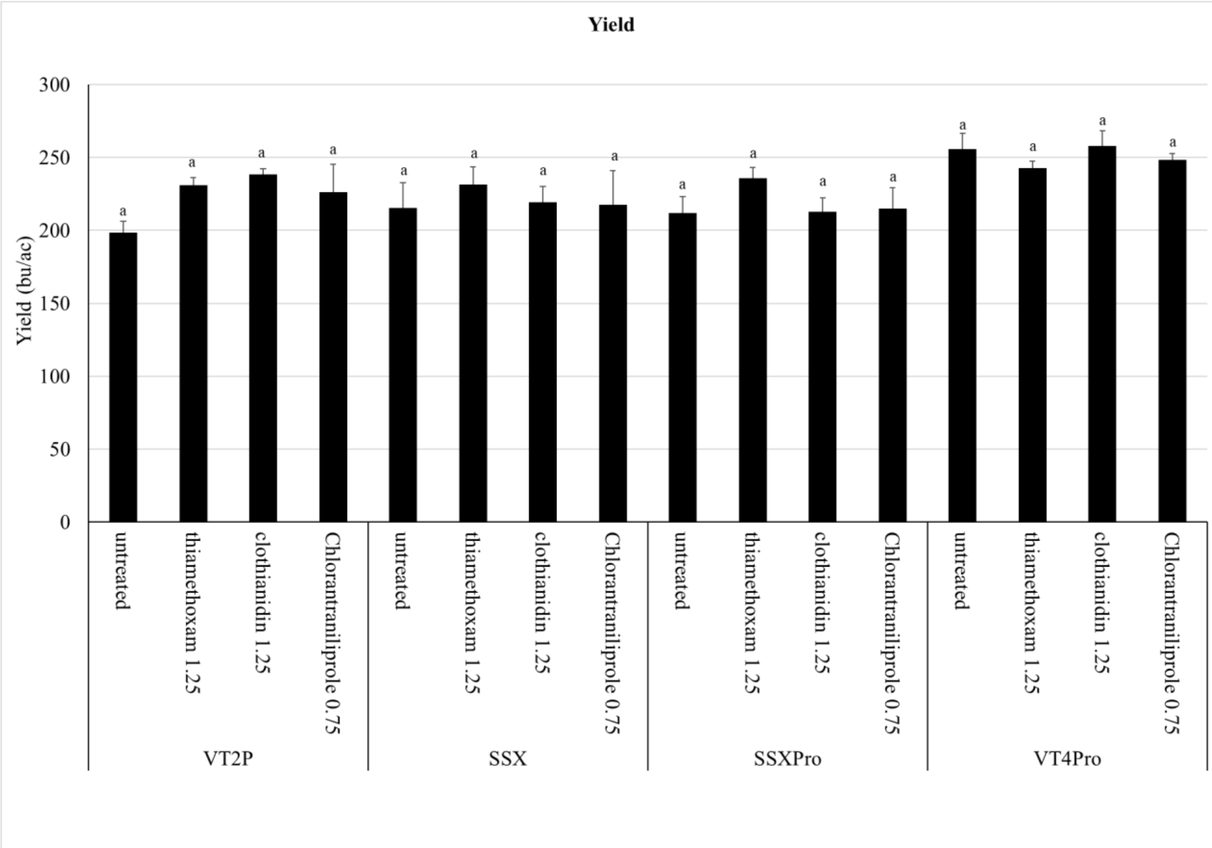


**Figure 4.** Grain yield for corn plants in the field trials in RROC in 2024. VT2P: a non-Bt corn hybrid, SSX: a SmartStax Bt corn hybrid containing Cry3Bb1 and Cry34/35Ab1 Bt proteins effective against rootworms, VT4Pro: a VT4Pro Bt corn hybrid with Cry3Bb1, and DvSnf7 dsRNA for targeting rootworms, and SSPro: a SmartStax Pro Bt corn hybrid with Cry3Bb1, Cry34/35Ab1 and DvSnf7 dsRNA for targeting rootworms. Clothianidin 1.25: seed treatment at 1.25 mg/seed, thiamethoxam 1.25: seed treatment at 1.25 mg/seed, Chlorantraniliprole 0.75: seed treatment at 0.75 mg/seed, and untreated seed. Treatment means with the same letter indicate no significant statistical differences.

In SWROC, the stand count data revealed an average of 32,343 corn plants per acre, which was more than that observed in RROC, but with no significant differences among seed treatments and Bt traits (Figure 5). Root injury was relatively low for the test site probably due to flooded fields and late planting with respect to rootworm egg hatch (Figure 6). NIS ranged from 0.43 to 1.04 for non-Bt RW corn hybrids across different insecticide seed treatments (Figure 6). No significant differences were detected in root injury among the non-Bt RW corn treated with clothianidin, thiamethoxam, chlorantraniliprole, or untreated seed, which suggests that the efficacy of these insecticide seed treatments is not significant in reducing CRW injury, probably due to the impact of heavy rain. In contrast, all Bt corn hybrids provided better control compared to non-Bt, indicating that the Bt traits are still effective for these populations. Additionally, the percentage of lodged plants in non-Bt RW corn ranged from only 0.9% to 6.4% (Figure 7), indicating low insect pressure. Moreover, no significant differences were detected in the percentage of lodged plants among all treatments, regardless of Bt or non-Bt, treated or untreated. The percentage of lodged plants and root injury for Bt hybrids only ranged from 0.2% to 2.6% and 0 to 0.08, respectively. No differences were observed among the different insecticide seed treatments within any single Bt trait. The overall yield data showed that Bt traits had more yields compared to non-Bt, either statistically or numerically (Figure 8). However, on the non-Bt RW corn, seed treatments of clothianidin, thiamethoxam, chlorantraniliprole showed no differences in yields compared to untreated seed (Figure 8), suggesting limited efficacy of these seed treatments in increasing the yield. As mentioned above, in 2024, excessive seasonal rainfall during the peak of CRW hatching period was probably significantly affected CRW survival in the test location, because this delayed the planting of corn plants and also created waterlogged conditions that disrupted egg/larval survival and feeding, collectively suppressing CRW damage.

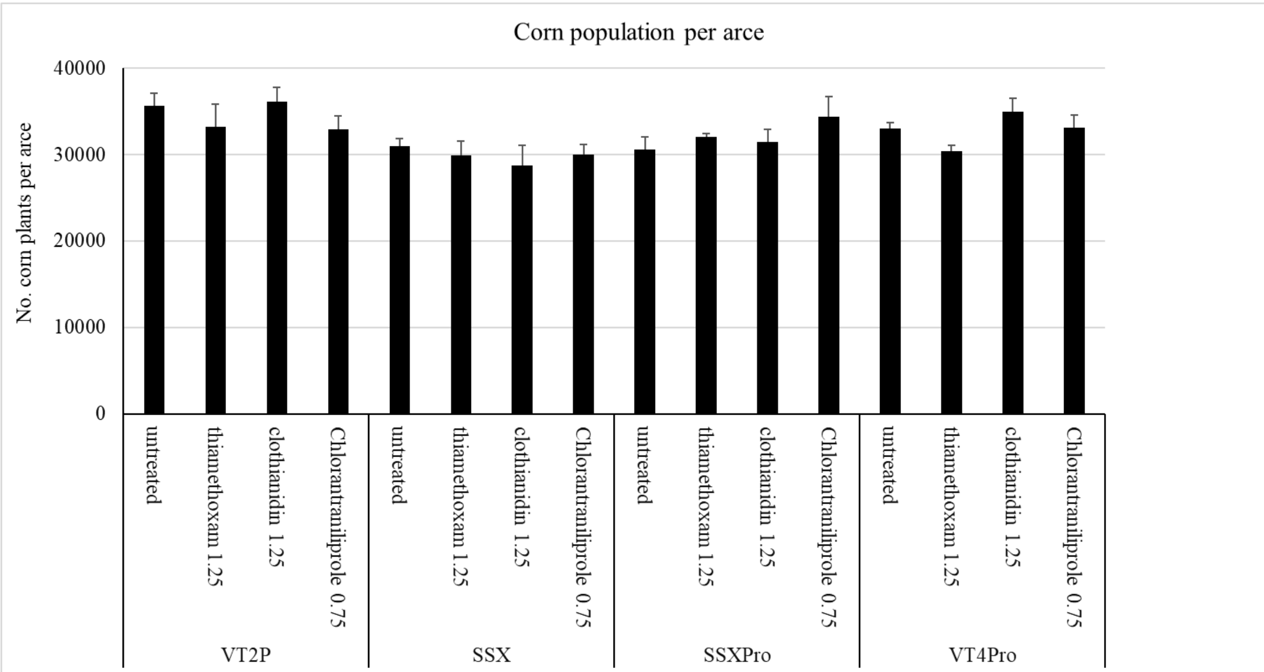


**Figure 5.** Estimated number of corn plants per acre based on the stand count in the field trials in SWROC in 2024. VT2P: a non-Bt corn hybrid, SSX: a SmartStax Bt corn hybrid containing Cry3Bb1 and Cry34/35Ab1 Bt proteins effective against rootworms, VT4Pro: a VT4Pro Bt corn hybrid with Cry3Bb1, and DvSnf7 dsRNA for targeting rootworms, and SSPro: a SmartStax Pro Bt corn hybrid with Cry3Bb1, Cry34/35Ab1 and DvSnf7 dsRNA for targeting rootworms. Clothianidin 1.25: seed treatment at 1.25 mg/seed, thiamethoxam 1.25: seed treatment at 1.25 mg/seed, Chlorantraniliprole 0.75: seed treatment at 0.75 mg/seed, and untreated seed.

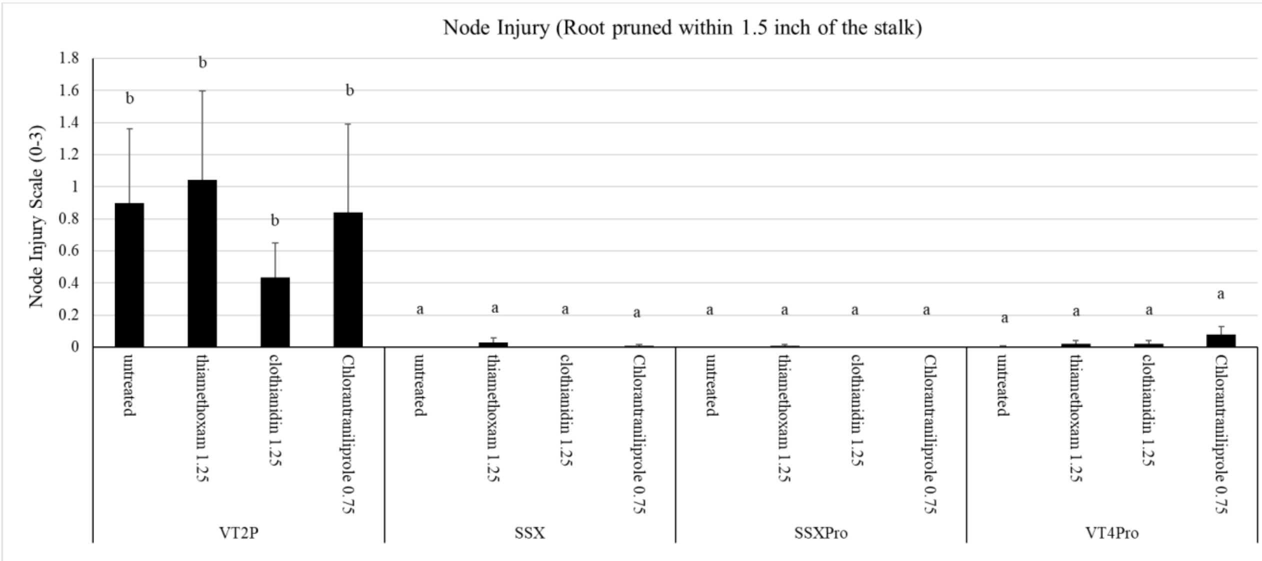


**Figure 6.** Corn root injury based on the Iowa State University's 0-3 Node Injury Scale in the field trials in SWROC in 2024. VT2P: a non-Bt corn hybrid, SSX: a SmartStax Bt corn hybrid containing Cry3Bb1 and Cry34/35Ab1 Bt proteins effective against rootworms, VT4Pro: a VT4Pro Bt corn hybrid with Cry3Bb1, and DvSnf7 dsRNA for targeting rootworms, and SSPro: a SmartStax Pro Bt corn hybrid with Cry3Bb1, Cry34/35Ab1 and DvSnf7 dsRNA for targeting rootworms. Clothianidin 1.25: seed treatment at 1.25 mg/seed, thiamethoxam 1.25: seed treatment at 1.25 mg/seed, Chlorantraniliprole 0.75: seed treatment at 0.75 mg/seed, and untreated seed. NS means no significant statistical differences. * Indicates significant statistical differences.

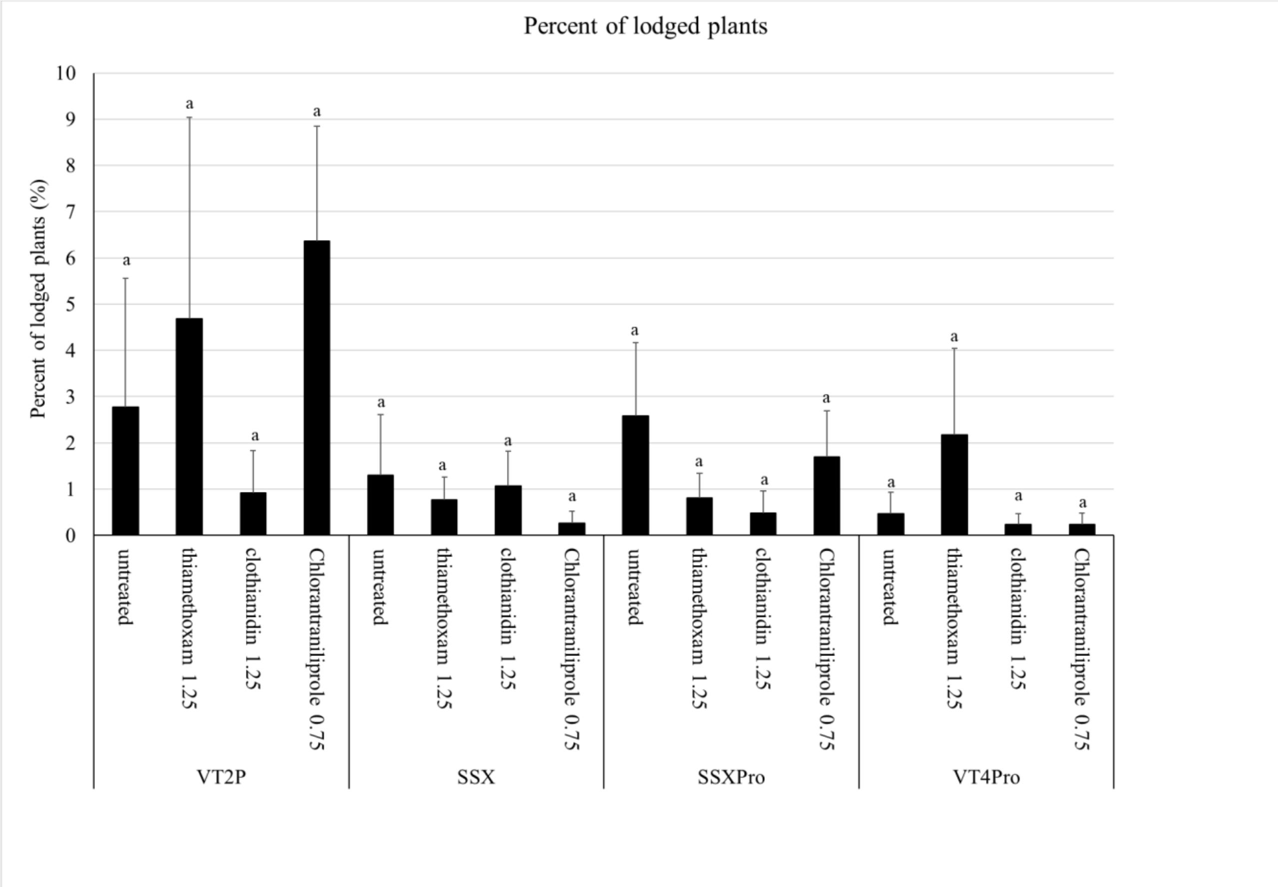


**Figure 7.** Percentage of lodged plants due to root injury from corn rootworm larvae in the field trials in SWROC in 2024. VT2P: a non-Bt corn hybrid, SSX: a SmartStax Bt corn hybrid containing Cry3Bb1 and Cry34/35Ab1 Bt proteins effective against rootworms, VT4Pro: a VT4Pro Bt corn hybrid with Cry3Bb1, and DvSnf7 dsRNA for targeting rootworms, and SSPro: a SmartStax Pro Bt corn hybrid with Cry3Bb1, Cry34/35Ab1 and DvSnf7 dsRNA for targeting rootworms. Clothianidin 1.25: seed treatment at 1.25 mg/seed, thiamethoxam 1.25: seed treatment at 1.25 mg/seed, Chlorantraniliprole 0.75: seed treatment at 0.75 mg/seed, and untreated seed. Treatment means with the same letter indicate no significant statistical differences.

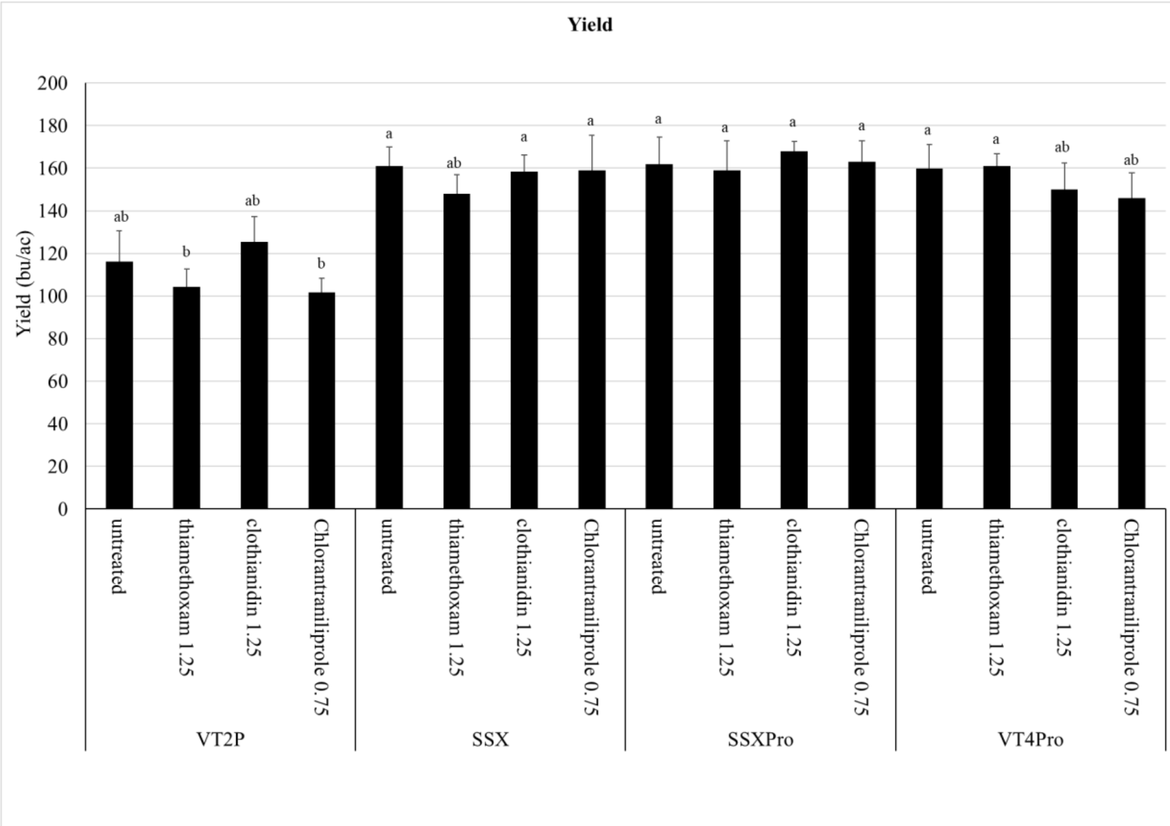


**Figure 8.** Grain yield for corn plants in the field trials in SWROC in 2024. VT2P: a non-Bt corn hybrid, SSX: a SmartStax Bt corn hybrid containing Cry3Bb1 and Cry34/35Ab1 Bt proteins effective against rootworms, VT4Pro: a VT4Pro Bt corn hybrid with Cry3Bb1, and DvSnf7 dsRNA for targeting rootworms, and SSPro: a SmartStax Pro Bt corn hybrid with Cry3Bb1, Cry34/35Ab1 and DvSnf7 dsRNA for targeting rootworms. Clothianidin 1.25: seed treatment at 1.25 mg/seed, thiamethoxam 1.25: seed treatment at 1.25 mg/seed, Chlorantraniliprole 0.75: seed treatment at 0.75 mg/seed, and untreated seed. Treatment means with the same letter indicate no significant statistical differences.

2.) IDENTIFY ANY SIGNIFICANT FINDINGS AND RESULTS OF THE PROJECT TO DATE.

Our data suggest that high-rate insecticide seed treatments, including clothianidin (1.25 mg/seed), thiamethoxam (1.25 mg/seed), and chlorantraniliprole (0.75 mg/seed), provide variable control of rootworms compared to untreated seed. At both ROCs, non-Bt treatments with clothianidin and thiamethoxam showed numerical reductions in NIS and lodging rates. However, these reductions were neither statistically significant nor consistent, likely due to variations in pest pressure and environmental conditions.

These findings highlight the need to evaluate seed treatment effectiveness on a field-specific basis. Meanwhile, Bt traits such as Cry3Bb1, Cry34/35Ab1, and RNAi (DvSnf7 dsRNA) remained effective against rootworm larvae at both locations, indicating that some WCR populations are still susceptible. The persistence of this susceptibility across the state suggests a mosaic resistance pattern in WCR populations.

3.) CHALLENGES ENCOUNTERED. (*Describe any challenges that you encountered related to project progress specific to goals, objectives, and deliverables identified in the project workplan.*)
No challenges were found during this period.

4.) FINANCIAL INFORMATION (*Describe any budget challenges and provide specific reasons for deviations from the projected project spending.*)
No budget challenges were found during this period.

5.) EDUCATION AND OUTREACH ACTIVITES. *(Describe any conferences, workshops, field days, etc attended, number of contacts at each event, and/or publications developed to disseminate project results.)*

1. Hunter, D.N., Koch, R., **Yang, F.**, Evaluating the efficacy of insecticidal seed treatments (IST) for managing soil insect pests in Bt and non-Bt corn. The Entomological Society of America Meeting, Phoenix, AZ, Nov 10-13, 2024.
2. Stahl, L., **Yang, F.,** 2024. Strategic Farming: Let's talk crops focused on corn insect pests. MN Crop News, https://blog-crop-news.extension.umn.edu/2024/03/strategic-farming-lets-talk-crops_18.html
3. Wangila, D., **Yang, F.,** 2024. Scouting for corn rootworm. MN Crop News, https://blog-crop-news.extension.umn.edu/2024/08/scouting-for-corn-rootworm.html
4. **Yang, F.,** 2024. Management of corn insect pests: foliar & soil insecticides and seed treatment. 2024 CPM Short Course and MCPR Trade Show. Dec. 10-12th, Minneapolis, MN.
5. **Yang, F.,** 2025. Corn Rootworm Management & Foliar Insect Update. 2025 MNICCA Conference, Feb. 19th, St. Cloud, MN.
6. **Yang, F.,** 2025. Research Update for Management of Corn Rootworm and European Corn Borer. 2025 Research Update for Ag Professionals in Willmar, MN. Jan. 14th, Willmar, MN.
7. **Yang, F.,** 2025. Research Update for Management of Corn Rootworm and European Corn Borer. 2025 Research Update for Ag Professionals in Lamberton, MN. Jan. 15th, Lamberton, MN.
8. **Yang, F.,** 2025. Strategic Farming: Keeping track of changes in corn insect challenges. Feb. 26th, 2025, Webinar.
9. **Yang, F.,** Hunter N., and Dwyer T., Seed treatment for corn rootworm control and Bt resistance in European corn borer. 2025 MN AG Expo, Mankato, Jan 22-23, 2025.
10. **Yang, F.,** Potter, B. 2024. Scouting & decision making for corn rootworms & European corn borer. UMN Field School for Ag Professionals, July 31, 2024.