FINAL REPORT

PROJECT TITLE: Risk and Management of Goss Wilt of Corn"
PROJECT NUMBER: 4098-13SP
PRINCIPAL INVESTIGATOR AND CO-INVESTIGATOR(S): Dean Malvick, University of Minnesota, St. Paul

ABSTRACT and SUMMARY
Goss's wilt is a significant corn disease in Minnesota that can reduce yields over 40% on susceptible hybrids. This disease, caused by the bacterial pathogen (*Clavibacter michiganensis* subsp. *nebraskensis*), was first confirmed in Minnesota in 2009 and has spread across the corn production region of Minnesota. New infected fields have been reported yearly. There has been limited information available upon which to improve and tailor management practices for Minnesota for the short and long term. The overall goal of this project was to address key gaps in information needed to understand disease risk and to improve management. The first objective was to determine if there is pathogenic variability in populations of the Goss's wilt pathogen that threatens durability and efficacy of resistance in resistant hybrids. Results from our greenhouse and field studies clearly show that aggressiveness of the Goss's wilt pathogen (CMN) is highly variable, with strains existing in Minnesota that range from non-pathogenic to highly aggressive on hybrids susceptible to Goss's wilt. Thus, the population of the pathogen in a particular field can influence the level of disease severity and yield loss. The presence of the non-pathogenic strains can reduce can reduce the severity of Goss's wilt. Corn hybrids and lines tested against a diversity of strains have demonstrated varying degrees of resistance and tolerance to infection and disease development. None of the hybrids were completely resistant to any strain and we did not identify races of the Goss's wilt pathogen that have the ability to overcome resistance on some hybrids and not others. Another objective was to determine survival of the Goss's wilt pathogen in infected corn residue that was buried at different depths or left on the surface under different conditions. The results generally suggest that that the Goss's wilt pathogen survives longer in residue on the soil surface than when it is buried. The last objective was to determine in field studies if foliar fungicide applications to corn can influence development of Goss's wilt. Based on preliminary analysis, we did not detect significant effects of the fungicide applications on disease development or yield under the conditions of these studies. In conclusion, the results demonstrate that multiple factors influence development of Goss's wilt, including hybrid resistance, strain or strains of the pathogen present in a field, survival of the pathogen, and weather conditions in July. These results have direct applications to improving management of Goss's wilt in the short term and long terms.

INTRODUCTION and BACKGROUND
Goss's wilt is a relatively new disease affecting corn production in fields scattered across Minnesota that can reduce yields over 40% on susceptible hybrids. First confirmed in Minnesota in 2009, this disease has since spread across the corn production region of Minnesota. As is the case for most crop diseases,

it is has a scattered presence across the landscape and inconsistent occurrence from year to year. Although we know that development of Goss's wilt is driven in part by weather, hybrid, and cropping history, the range of risk factors that favor Goss's are not understood and we cannot predict when, where, and how much damage this disease will cause.

Goss's wilt is the only significant corn disease in Minnesota is caused by a bacterial pathogen (*Clavibacter michiganensis* subsp. *nebraskensis*). There are no chemical sprays that have yet been shown to be consistently effective for management. The pathogen overwinters in infested corn residue. It infects plants that have been wounded by strong wind and thunderstorms and hail, and is favored by planting corn-on-corn. Much more research-based information was needed to reduce risk and to improve disease management

Problem Statement: Although **c**orn producers in Minnesota have historically had few significant problems with leaf diseases, this changed with the emergence of Goss's leaf blight and wilt. The pathogen is now widespread in corn fields across the state, and thus widely increasing the risk of disease. Management of Goss's wilt is based on genetic resistance, although crop rotation and tillage are also important. However, these practices have not prevented yield loss in all fields, and there is a paucity of information available upon which to improve and tailor management practices for Minnesota for the short and long term.

OBJECTIVE AND GOAL STATEMENTS

i. *Determine if there is pathogenic variability in the populations of the Goss's wilt pathogen that threatens durability of resistant hybrids.* Based on field observations and preliminary research, we hypothesized that the Goss's wilt pathogen has different strain types with different aggressiveness that influence the level of effective resistant in hybrids.
ii. *Determine which factors influence survival and spread of the Goss's wilt pathogen in a field and area.* Our hypothesis was that burial of corn residue and tillage may reduce the risk of Goss's wilt in particular fields, and this will be influence by environment.
iii. *Determine if application of foliar fungicides can increase incidence and severity of Goss's wilt.* Following scattered anecdotal observations, we hypothesize that application of foliar fungicides can potentially increase severity of Goss's wilt under some conditions.

MATERIALS AND METHODS

i. Resistant hybrids are central to management of Goss's wilt, but our preliminary research suggested that no hybrids are immune and all hybrids are not equally resistant to all populations of the Goss's wilt pathogen. In field and greenhouse studies conducted over two growing seasons, we obtained a set of corn hybrids with different levels of resistance to Goss's wilt from different companies and we inoculated them with a collection of strains of the Goss's wilt pathogen that we collected across the region. The levels of damage to the corn were measured based on symptom severity and yield to determine if the isolates vary in aggressiveness and if some can overcome resistance in some corn hybrids. We also conducted analysis of key genetic characteristics in the pathogen related to pathogenicity.
ii. The environmental and agronomic factors that influence survival and spread of the Goss's wilt pathogen are poorly understood. We used plots in fields at two field locations (Rosemount and Waseca, MN) to study survival of the pathogen when infected corn residue is buried at different depths or left on the surface (to mimic different types of tillage). Samples were collected at several time points following their placement in the studies, and the survival and infectivity of the pathogen was determined using plant inoculations and laboratory methods.

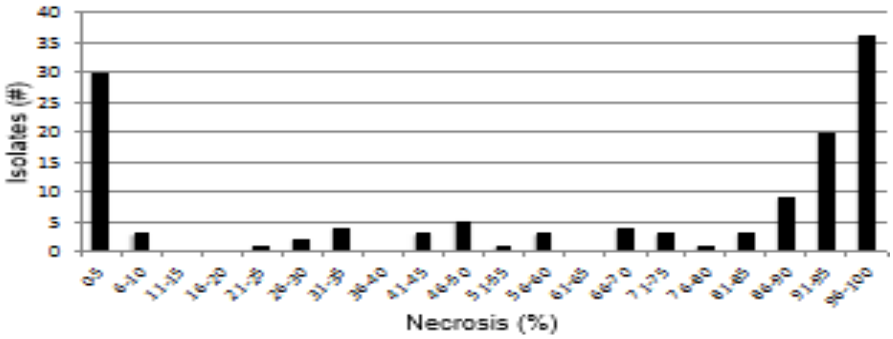
iii. Field observations have suggested that some bacterial diseases, including Goss's wilt of corn and bacterial leaf streak of wheat, could possibly increase after foliar fungicide applications. We set up field studies in two growing seasons to test this idea. Spray applications of a fungicide premix (triazole + strobilurin) without adjuvants added were made at two different timings (V6 and VT stages) before and after inoculation of the corn with the Goss's wilt pathogen. Subsequent disease development was measured and grain yields were taken in all plots.

RESULTS AND DISCUSSION

Objective i: The results from our greenhouse and field studies clearly show that aggressiveness of the Goss's wilt pathogen (CMN) is highly variable, with strains existing in Minnesota that range from non-pathogenic to highly aggressive on hybrids susceptible to Goss's wilt (see Figure below). These results have several implications. One is that the population of the pathogen in a particular field can influence the level of disease that develops and the level of yield loss. Another is that the non-aggressive strains can confound disease diagnosis, possibly resulting in false positive diagnosis of Goss's wilt. In addition, in other experiments that we have done by inoculating corn with a mixture of pathogenic and non-pathogenic strains of this pathogen, the results suggests that presence of the non-pathogenic strains can reduce can reduce the severity of disease that develops. This later result was a surprise, and additional experiments are needed to understand the importance and potential of these interactions among strains.

Corn hybrids and lines tested against a diversity of strains of the Goss' wilt pathogen in greenhouse studies have demonstrated varying degrees of resistance and tolerance to infection and disease development. None of the hybrids were were completely resistant to any strain, and none of the inoculations indicated that there are races of the Goss's wilt pathogen that have the ability to overcome resistance on some hybrids and not others. Our preliminary studies to understand genetic factors that may control aggressiveness have suggested that the pathogen may use mechanisms to infect corn that are different than those used by related bacterial pathogens. These results could be valuable to enhance our understanding of resistance and how to improve it in corn hybrids.

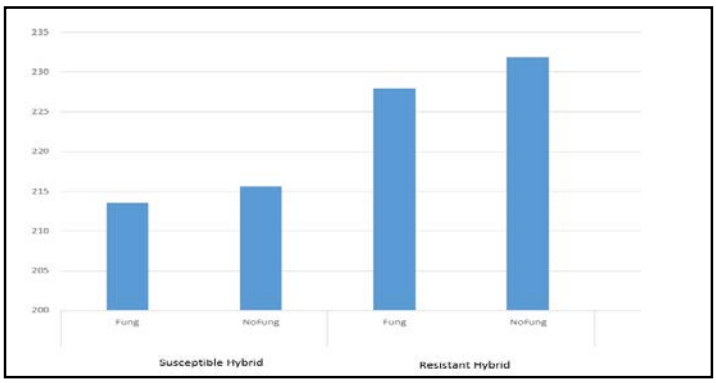
Lastly, when we started these studies, we had methods to inoculate plants with the pathogen that seemed to be effective in our limited work up to that point. However, as we proceeded with our research, key limitations of these methods became clear and we needed to develop and test other methods. Our work with different methods to inoculate greenhouse and field plots with the Goss's wilt pathogen has identified new, effective, and high-throughput methods that enable us to conduct new kinds of important research on management of Goss's wilt.



Virulence profile of *Cmn* culture collection. Most *Cmn* isolates were highly virulent while a large minority were unable to initiate disease development. Data represents 130 *Cmn* isolates. All corn plants were inoculated with $1*10^7$ CFU/ml via stock needle injection. Necrosis represents whole plant necrosis measured three weeks post-inoculation in the greenhouse.

Objective ii**.** The results from our studies at two field locations (Rosemount and Waseca, MN) to study survival of the Goss's wilt pathogen when infected corn residue is buried at different depths or left on the surface have been inconsistent. Our first experiment with burial of infected corn residues with demonstrated decreased survival/infectivity of the Goss's wilt pathogen after one year. The second experiment suggested that the pathogen may not have survived on the soil surface or when buried under the different environmental conditions (e.g. wetter) that were present in the first study within one year. Thus, overall the results have been inconclusive, but they generally support the idea that the Goss's wilt pathogen survives better in residue on the soil surface than when it is buried. In addition, the weather (wet or dry) may influence the survival.

Objective iii. The results from our field studies in 2014 and 2015 at Rosemount, MN to determine if foliar fungicide applications to corn can influence development of Goss's wilt were inconclusive based on our preliminary analysis. Although there were some trends suggesting that there could be some treatment effects based on fungicide applications (see Figure below), the results were highly variable between replicated plots in both years and thus detection of significant treatment effects was difficult. We just obtained the final data from Rosemount this week, and we will be doing additional analyses to compare and finalize results.



Comparison of mean grain yields between field plots sprayed with fungicides or not sprayed
With fungicides for two corn hybrids (susceptible and moderately resistant to Goss's wilt)
in experiments at Rosemount, MN in 2015. High levels of Goss's wilt developed in these inoculated plots. Yield differences were not significant based based on preliminary analysis.

CONCLUSIONS

- Goss's wilt is a new, significant, and spreading disease in Minnesota, central U.S.A., and Canada. We have continued to confirm this disease in new fields in MN every year since 2009.
- Midwestern populations of the Goss's wilt pathogen (CMN) are highly variable in aggressiveness, with some highly aggressive and some with low very low aggressiveness that did not cause Goss's wilt.
- There is no clear evidence for races of Cmn, but pathogenic variability can influence disease development in susceptible/resistant hybrids. Corn hybrids vary widely in resistance to the different aggressive isolates, but none tested are immune.
- Leaf disease severity and incidence ratings taken at different times during the field studies were generally poorly correlated with yield reduction due to disease.

- Results in survival studies with the Goss's wilt pathogen, generally support the idea that the Goss's wilt pathogen survives better in residue on the soil surface than when it is buried and the survival is influenced by the field environment.
- In studies of the potential effects of foliar fungicide applications on Goss's wilt development, our preliminary analysis did not detect significant effects among the treatments for Goss's wilt development.

EDUCATION, OUTREACH, AND PUBLICATIONS

Presentation titles, conferences, and total number of crop consultants and farmers attending [numbers in brackets] where results from these studies were presented:

- Barriers to Bushels Conference, February 2015. Wilmar, MN [40]
- Crop Production Field Day. July 2015. Morris, MN [22)
- Research Update Conference. January 2015. Waseca, MN [75]
- Research Update Conference. January 2015. Kasson, MN [83]
- Research Update Conference. January 2015. Lamberton, MN [45]
- Research Update Conference. January 2015. Willmar, MN 66]
- Research Update Conference. January 2015. Morris, MN [77]
- Barriers to Bushels Conference, February 2014. Wilmar, MN [45]
- Research Update Conference. January 2014. Waseca, MN [81]
- Research Update Conference. January 2014. Kasson, MN [79]
- Research Update Conference. January 2014. Lamberton, MN [48]
- Research Update Conference. January 2014. Willmar, MN 62]
- Research Update Conference. January 2014. Morris, MN [70]
- Pesticide Applicator Training. St. Cloud, MN January 2014 [56]
- Crop Pest Management Short Course, December 2014. Minneapolis, MN [120]
- Winter Crops Day. January 2013. Kasson, MN [61]
- Winter Crops Day, January 2013. Waseca, MN [85]
- Advanced Field Crop Workshop on Goss's Wilt. August 2014, Crookston, MN [21]
- Goss's Wilt Field Workshop. August 2013, Rosemount, MN [27]

<u>Scientific Conferences</u>

- Malvick, D.K Presented results at a Goss's Wilt Symposium held in East Lansing, MI June 2015.
- Malvick, D.K., Curland, R., Ishimariu, C., and McNally, R. Goss's Leaf Blight & Wilt of Corn in Minnesota: A 'New' and Poorly Understood Corn Disease. Presented at the National Corn Disease Working Group annual meeting. Chicago, IL. December 2013.
- Malvick, D.K. October 2013. Invited seminar presented to Department of Plant Pathology at North Dakota State University. Fargo, North Dakota. Title of presentation: "Goss's Leaf Blight & Wilt of Corn: A 'New' and Poorly Understood Disease of Corn in the Upper Midwest".
- Malvick, D.K September 2013. Seminar presented to the Department of Plant Pathology at the University of Minnesota. St Paul, Minnesota. Title of presentation: "Goss's Leaf Blight and Wilt - Biology & Potential Risks of this `New' & Poorly Understood Corn Disease in Minnesota".
- R. R. McNally (1), C. A. Ishimaru (2), D. K. Malvick. <u>2015 APS. Meeting | Novel PCR-mediated assay for detection, identification and quantification of Clavibacter michiganensis subsp. nebraskensis</u>

- Malvick, D. K., Curland, R. D., Ishimaru, C. A., Floyd, C., and McNally, R. R. 2014. Characteristics of resistance to Goss's wilt of corn in Minnesota caused by *Clavibacter michiganensis* subsp. *nebraskensis*. Poster presented at the National American Phytopathological Society (APS) Meeting in Minneapolis, MN 2014 Phytopathology. (www.apsnet.org/meetings/Documents/ 2014_meeting_abstracts/aps2014abP417.htm).
- McNally, R. R., Curland, R. D., Ishimaru, C. A., and Malvick. D. K. 2014. Evaluation of virulence potential and host resistance to the Goss's wilt pathogen *Clavibacter michiganensis* subsp. *nebraskensis*. Poster presented at the National APS Meeting in Minneapolis, MN 2014. (www.apsnet.org/meetings/Documents/2014_meeting_abstracts/aps2014abP416.htm).
- McNally, R. R., Curland, R. D., Hoerth, S. E., Ishimaru, C. A., and Malvick. D. K. 2014. Characterization of *Clavibacter michiganensis* subsp. *nebraskensis* isolates in Minnesota. Phytopathology.Poster presented at the North Central Division APS Meeting in Madison, WI. 2014.

Web site and information sheet: http://www.extension.umn.edu/agriculture/crop-diseases/corn/gossbacterialwilt.html

Additional publications are in development.

.