Potential Unintended Consequences of Planting Drought Tolerant Staygreen Corn

PIs: F. Workneh, and Charlie Rush, Texas A&M AgriLife Research, Amarillo; Wenwei Xu, Texas A&M AgriLife Research and Texas Tech Univ., Lubbock; Ed Bynum, Texas A&M AgriLife Extension, Amarillo; Bridget Guerrero, WTAMU, Canyon, TX.

Abstract

In the Southern Ogallala Region, 4.4 million acres of corn are grown each year for feed grain and silage production and the sales value of the crop exceeds $2.4 billion. Over the past 10-15 years, yields have steadily increased, primarily due to development of staygreen hybrids with superior drought tolerance. Planting these hybrids has resulted in water conservation and significant increases in yields and profit. However, it also may have had the unintended consequence in some instances of providing an over-summering greenbridge host for the wheat curl mite (WCM) and the viruses they transmit, which subsequently resulted in epidemics of mite-vectored virus diseases (MVVD) in nearby wheat fields. Since wheat, at 9.1 million acres, is the major crop planted in this region, and MVVD significantly reduce water use efficiency, forage and grain yields, the potential for significant economic loss is high. Although genetic resistance to the majority of these viruses has been identified and incorporated into corn germplasm, susceptibility of the most commonly planted staygreen cultivars and their potential role in serving as an over-summering, greenbridge host for WCM, has not been studied. Removing susceptible corn cultivars and replacing them with drought tolerant cultivars with good resistance to WCM, and the viruses they transmit, would significantly reduce the risk for epidemics of MVVD and the associated waste of irrigation being applied to diseased wheat.

Project Narrative

The Southern Ogallala Region has 19.7 million acres of cropland and at 9.1 million acres wheat is by far the predominant crop planted in the area. Corn is the largest irrigated crop, at 2.8 million acres, but there are also 1.6 million acres of dryland corn production, a relatively new development that has occurred over the last 20 years, primarily due to development of improved drought tolerant cultivars (Amosson, et. al, 2014; Amosson and Guerrero, 2014).

Many of the corn hybrids planted in the Southern Ogallala Region stay green well past physiological maturity (Thomas and Ougham, 2014) and this staygreen trait, which is frequently associated with drought tolerance (Hou, et al., 2015; Lee and Tollenaar, 2007), may have unintended consequences. Wheat curl mites transmit a number of viral pathogens that include *Wheat streak mosaic virus* (WSMV), *Triticum mosaic virus* (TriMV) and *Wheat mosaic virus* (WMoV) (Skare, et al., 2003; Tatineni, et. al, 2009). Throughout the Southern Ogallala Region, the mite-vectored virus diseases (MVVD) Wheat Streak Mosaic, Triticum Mosaic and High Plains Disease, caused by these pathogens, respectively, are the predominant biotic constraint to economically sustainable wheat production (Burrows, et. al, 2009). These diseases not only impact wheat forage and grain production but also significantly reduce root growth and crop water use efficiency (Pradham, et al., 2015; Price, et al., 2010). One of the few effective management practices for MVVD is removal of volunteer wheat and other over-summering grass hosts before planting the wheat crop. However, corn is a known host for WCM (Seifers, et. al, 1997,1998) and the increased planting of drought tolerant corn cultivars that stay green much longer in the fall may have the unintended consequence of providing an over-summering, greenbridge host for the WCM that can’t be removed before wheat emergence. It is not uncommon to find late-planted wheat fields, which typically are safe from infection by WCM, severely affected by MVVD (Rush, personal observations). In many instances, the only common denominator among these fields has been an adjacent field of corn. Movement of WCM from wheat to corn in late spring is well-documented (Fritts, et al., 1999; Liu, et al., 2005). However, the potential for corn to serve as an over-summering, greenbridge host for movement of WCM to wheat in the fall, and subsequent development of MVVD in the wheat crop, has not been studied.

For corn to be an important epidemiological variable in the development of MVVD in wheat it would have to serve as a host for the WCM and for the viral pathogens they transmit, because the mites by themselves have minimal impact on the wheat crop. Fortunately, genetic resistance to WMoV and viruses in the *Potyviridae*, which include WSMV and TriMV, has been incorporated into many corn hybrids (Rodriguez-Ballesteros, et. al., 1996; Marcon, et. al., 1999; Jones, et. al., 2011). However, whether these genes actually confer resistance to TriMV has not been evaluated, nor has the potential for late maturing or staygreen corn hybrids to be epidemiologically important in development of MVVD in wheat. For this reason we plan to initiate studies with the following objectives:

Objectives. *1) Evaluate drought tolerant, staygreen maize hybrids and inbred lines as host for WCM and the viral pathogens they transmit and 2) Determine whether the susceptible lines from objective 1 can serve as an over-summering, greenbridge for viruliferous WCM and the potential economic consequences of increased disease in infected wheat.*

Approach. *Evaluate drought tolerant, staygreen maize hybrids and inbred lines as host for WCM and the viral pathogens they transmit.* This study will be conducted in the Plant Pathology Greenhouse, Texas A&M AgriLife, Bushland. Hybrid and inbred lines will be collected from a variety of sources (Dr. Wenwei Xu's breeding program and commercial seed companies) and screened for susceptibility to WCM, WSMV, TriMV and potentially WMoV. *Wheat streak mosaic virus* and TriMV are by far the most prevalent and important viral pathogens of wheat in the Southern Ogallala Region so they will be the focus of this study. Mite populations, viruliferous for one or more of the viruses of interest are routinely maintained by personnel in the plant pathology program and will be available for use in this project. Entries with resistance to spider mites, with and without associated drought tolerance, will be included, as will entries with different mechanisms and degrees of drought tolerance, with special focus on the staygreen attribute. (It is recognized that not all staygreen lines are drought tolerant but the focus of this project will be on drought tolerant lines with the staygreen trait because of their importance in the Southern Ogallala Region.) An entry with no known resistance to either WCM or any of the viruses will be used as a susceptible control. Each entry will be planted in the GH and approximately 2 weeks following emergence will be infested with WCM, viruliferous for WSMV, TriMV, WMoV, or a combination thereof. Plants will be infested by placing a wheat leaf infested with approximately 20 viruliferous mites into the whorl of the young corn plant. After approximately 3 weeks, mite numbers on infested plants will be counted and plant tissue will be tested for virus infection, using routine diagnostic procedures developed in our laboratory (qPCR and/or ELISA). There will be at least three replications, arranged in a randomized complete block, for each entry and the study will be repeated to verify results.

Determine whether the susceptible lines from objective 1 can serve as an over-summering, greenbridge for viruliferous WCM, and the potential economic consequences of increased disease in wheat, resulting from planting drought tolerant corn cultivars. This study will be conducted under the Plant Pathology center pivot on the south section of the USDA-CPRL, Bushland, TX. Around June 1 in each year of the study, lines from objective 1 that show to be good hosts for both WCM and viral pathogen/s will be evaluated in a replicated field trial. Appropriate susceptible and resistant corn entries will be included as controls, in addition to a non-host crop species. We also will include a late-planted, late maturing non-drought tolerant cultivar as a greenbridge control. Around June 1, each entry will be planted in a 3x3m plot replicated four times in a randomized block design. Plots will be separated from each other with a 7m border on all sides that will be drilled with wheat later in the season. During the summer growing season, corn entries will be monitored for WCM and virus infection, using well established technical procedures developed in our laboratory. Briefly, for mite monitoring, corn leaves will be collected, taken to the lab and washed with an alcohol/soap solution which releases the mites. Then the solution plus mites are run through a vacuum filter and mites are counted. For monitoring pathogen presence and titer, qPCR will be used.

Approximately September 15, winter wheat will be drilled into the border areas around the corn plots and after emergence the wheat will be monitored for WCM and virus infection. Mite movement from corn into wheat will be monitored in a similar fashion as corn leaves and wheat infection by the different viruses will be monitored by qPCR. In addition, disease incidence and severity will be measured at 1 m intervals downwind from each corn plot, using a hyperspectral radiometer and evaluating reflectance at 555nm. This wavelength corresponds well with visual disease symptoms of MVVD (Workneh, et al., 2009). Corn that serves as a greenbridge for viruliferous WCM will become a focal pointsource for disease initiation in the surrounding wheat crop. Based on methodology used by Almas, et al., 2016, scenarios portraying various levels of MVVD incidence and severity will be used to estimate potential economic losses in wheat associated with the unintended consequences of corn serving as an over-summering, greenbridge host. This methodology has been used successfully in previous studies.

Data Analysis. For the greenhouse study, the numbers of mites observed on each plant entry and titer levels in plant samples will be analyzed using a mixed model ANOVA in which the treatments are fixed effects and blocks as random effects. For the field study, gradients of mite numbers and WSM severity levels (based on reflectance values) away from the corn plots will be analyzed using regression. Slopes away from the different corn plots will be compared for differences, using mixed models. Steeper regression slopes in terms of mite numbers and WSM severity levels indicate greater impact of the corn plots on disease development in the wheat.

Expected Outcomes. The most significant outcome of this project will be the determination of whether some commonly grown drought tolerant, staygreen corn cultivars can serve as over-summering, greenbridge hosts for viruliferous WCM and whether these cultivars are epidemiologically important with regard to MVVD in wheat. If such lines are identified, we will estimate potential economic impact, based on the work of Almas, et al., 2016. Results will be rapidly provided to seed companies and growers through oral presentations at field days, grower meetings, and radio interviews. Stories and information resulting from this study will be posted on AgriLife Today, the AgriLife communications website, it will be sent to the AgNMore list serv, which has 700-plus subscribers, and it will be marketed to more than 100 local media and industry contacts through a direct email from our Communications Specialist, Kay Ledbetter.

Relevant Publications
Amosson, S. H**.**, **B. Guerrero**, and R. Dudensing. 2014. “The Impact of Agribusiness in the High Plains Trade Area: 6th Edition.” Edited by Kay Ledbetter. Texas A&M AgriLife Research and Extension Center, Amarillo, Texas.

Hao, B. **Q. Xue**, T.H. Marek, K.E. Jessup, J. Becker, X. Hou, **W. Xu**, **E.D. Bynum**, B.W. Bean, P.D. Colaizzi, and T.A. Howell. 2015. Water use and grain yield in drought-tolerant corn in the Texas High Plains. Agron. J. 107(5): 1922-1930.

Price, J.A., Simmons, A.R., Rashed, A., **Workneh, F**., and **Rush, C.M.** 2014. Winter Wheat Cultivars with Temperature Sensitive Resistance to *Wheat streak mosaic virus* Do Not Recover from Early Season Infections. Plant Disease 98(4):525-531.

Workneh, F., Price, J. A., Jones, D. C., and **Rush, C. M.** 2010. Wheat Streak Mosaic: A Classic Case of Plant Disease Impact on Soil Water Content and Crop Water-Use Efficiency. Plant Disease. 94: 771-774.

Chen, J., Xu, W., Velten, J., Xin, Z. and Stout, J. 2012. Characterization of maize inbred lines for drought and heat tolerance. Journal of Soil and Water Conservation: Special Issue on “Climate Change Mitigation”. 67(5): 354-364.

Dong, X.; Xu, W.; Zhang, Y.; Leskovar, D.I. 2016. Effect of Irrigation Timing on Root Zone Soil Temperature, Root Growth and Grain Yield and Chemical Composition in Corn. Agronomy 6(34): doi:10.3390/agronomy6020034

Literature Cited

Almas, L. K., Price, J. A., **Workneh, F.,** and **Rush, C. M.** 2016. Quantifying economic losses associated with levels of wheat streak mosaic incidence and severity in the Texas High Plains. Crop Protection (accepted).

Amosson, S. H**.**, **B. Guerrero**. 2014. The impact of the small grains industry in the Southern Ogallala Region. Texas A&M AgriLife Extension Bulletin AG-012. Texas A&M University, College Station (14 pp).

Amosson, S. H**.**, **B. Guerrero**, and H. Graham. 2014. The impact of the feed grains industry in the Southern Ogallala Region. Texas A&M AgriLife Extension Bulletin AG-011. Texas A&M University, College Station (14 pp).

Burrows, M. E., **Rush, C. M.**, and Franc, G. D. 2009. Occurrence of viruses in winter wheat in the Great Plains region. Plant Health Prog. (http://www.plantmanagementnetwork.org/php).

Fritt, D.A., G.J. Michels, Jr., and **C.M. Rush**. 1999. The effects of planting date and insecticide treatments on the incidence of High Plains Disease in Corn. Plant Disease 83: 1125-1128
.
Hao, B. **Q. Xue**, T.H. Marek, K.E. Jessup, J. Becker, X. Hou, **W. Xu**, **E.D. Bynum**, B.W. Bean. 2015. Soil water extraction, water use, and grain yield by drought-tolerant maize on the Texas High Plains. Agric. Water Mang. 155:11-21.

Jones, M. W., Boyd, E. C., and Redinbaugh, M. G. 2011. Responses of Maize (Zea mays L.) Near Isogenic Lines Carrying Wsm1, Wsm2, and Wsm3 to Three Viruses in the Potyviridae. Theor Appl Genet 123: (5) 729-740.

Lee, E. A., and Tollenaar, M. 2007. Physiological basis of successful breeding strategies for maize grain yield. Crop Sci. 47(S3): S202-S215.

Liu J., Lee E.A., Sears, M.K., and Schaafsma, A.W. 2005. Wheat curl Mite (Acari: Eriophyidae) Dispersal and Its Relationship with Kernel Red Streaking in Maize. J. Econ. Entomol. 98: (5) 1580-1586.

Marçon, A., Kaeppler, S. M., Jensen, S. G., Senior, L., and Stuber, C. 1999. Loci Controlling Resistance yo High Plains Virus and Wheat Streak Mosaic Virus in A B73 Mo17 Population of Maize. Crop Sci. 39: (4) 1171-1177.

Pradhan, G., **Xue, Q**., Jessup, K. Hao, B., Price, J., and **Rush, C. M.** 2015. Physiological Responses of Hard Red Winter Wheat to Infection by *Wheat streak mosaic virus*. Phytopathology 105: (5) 621-627.

Price, J. A., **Workneh, F**., Evett, S.R., Jones, D. C., Arthur, J., and **Rush, C. M.** 2010. Effects of wheat streak mosaic virus on root development and water-use efficiency of hard red winter wheat. Plant Disease 94: 766-770.

Rodriguez-Ballesteros, O. R., Marcon, A., Frederiksen, R. A., **Rush, C. M**., Heidel, G., Jeffers, D., Kaeppler, S., and Jensen, S. 1996. Genetics of resistance to High Plains Disease in maize. Pages 59-77 *In:* Proceedings High Plains Disease Symposium, **C. M. Rush** and G. J. Michels, Jr., eds. C&M Press, Denver, CO.

Seifers, D.L., Harvey, T.L., Martin, T.J., and Jensen, S.G. 1997. Identification of the Wheat Curl Mite as the Vector of the High Plains Virus of Corn and Wheat. Plant Disease 81: (10) 1161-1166.

Seifers, Dallas, L., Harvey, T.L., Martin, T.J., and Jensen, S.G. 1998. A Partial Host Range of the High Plains Virus of Corn and Wheat. Plant Disease 82: (8) 875-879.

Skare, J.M., I. Wijkamp, J. Rezende, G. Michels, **C. M. Rush**, K-B Scholthof, and H. Scholthof. 2003. Colony Establishment and Maintenance of the Eriophyid Wheat curl Mite *Aceria tosichella* for controlled transmission studies on a new virus-like pathogen. Journal of

Tatineni, S., Ziems, A. D., Wegulo, S. N., and French, R. 2009. Triticum mosaic virus: A Distinct Member of the Family Potyviridae with an Unusually Long Leader Sequence. Phytopathology 99: (8) 943-950.

Thomas, H., and Ougham, H. 2014. The stay-green trait. J. Exp. Bot. doi:10.1093/jxb/eru037.
Velandia-Parra, M., Rejesus, R., Jones, D. C., Price, J. A., **Workneh, F**., and **Rush, C. M.** 2010. Economic impact of the *Wheat streak mosaic virus* in the Texas High Plains. Crop Protection 29: 699-703.

Workneh, F., Jones, D. C., and **Rush, C. M.** 2009. Quantifying wheat yield across the field as a function of wheat streak mosaic intensity: a state space approach. Phytopathology 99:432-440.