INFLUENCE OF WEATHER CONDITIONS ON HARDLOCK SEVERITY

Daniel J. Mailhot
James J. Marois
David L. Wright
University of Florida, NFREC
Quincy, FL

Abstract

Hardlock typically results in yield losses of 30 to 60% in North Florida, but varies considerably by year. Previous studies have shown it to be associated with infection by *Fusarium verticillioides*. Disease severity has been linked to the number of flower thrips present in cotton flowers and to feeding damage in developing bolls caused by stinkbugs. This study investigates the effect of weather conditions on disease severity. Cool temperatures from 0000 to 0600 h resulted in more hardlock in bolls from that specific day. Years with cooler temperatures from 0000 to 0600 h during the period of bloom and increased temperature variability between dates had more hardlock. Years with more hardlock had lower yields, and hardlock appeared to be the most influential yield-limiting factor in the years examined.

Introduction

Hardlock is characterized as a failure of fiber to extend outward after boll opening. Affected locules remain in compressed wedges, and sometimes have a slightly pink appearance, due to the presence of *Fusarium verticillioides*. Flower inoculation on the day of bloom results in increased hardlock severity in the resulting bolls, and the pathogen is frequently isolated from symptomatic bolls. It has been hypothesized that *F. verticillioides* infects cotton flowers on the day of bloom (Marois and Wright, 2004), and sustains itself in the developing boll. The infection may result in changes to the developing boll, including fewer healthy seeds (more "hollow" seeds), degradation of the seed coat, and a slight flattening of the individual fibers (Srivastava et al., 2008).

Hardlock is a major problem in north Florida, and yield losses typically vary from 30 to 60%, depending on the year. Severity has been linked to the prevalence of flower thrips in flowers on the day of bloom (Mailhot et al., 2007). It has also been associated with feeding damage to developing bolls by stinkbugs (Willrich et al., 2004). Fungicide applications reduce hardlock in moderate and severe years, but are not effective in low hardlock years. Insecticide applications to control thrips numbers are generally effective, except in some low hardlock years. The recommended management strategy is application of fungicide and insecticides weekly for the first 4 or 5 weeks of bloom. This protects most of the flowers that will contribute to the final yield. The fungicide applications also appear to boost yield independently of the effect on hardlock by reducing leaf canopy diseases.

Hardlock severity varies considerably from year to year, but the cause of this variation has not been identified. Disease forecasting models are used in many crop production systems to obtain maximum benefit from spraying while reducing unnecessary applications. Applying control measures when most effective improves profitability while reducing environmental impact. The objectives of this study are to explore the relationship between hardlock and yield and identify weather variables that explain the variation in observed hardlock.

Materials and Methods

Impact of Hardlock on Yield

Data from unsprayed control and fungicide-treated plots were compiled from multiple studies in Marianna (2003-2005, 2007) and Quincy (2002-2007), FL. Some of these data have been reported previously, while others are unpublished or new. Plots were maintained according to standard production practices, with the exception of the experimental treatments applied. Cultivar DP555 was used in all cases except Quincy in 2002. The data reported here are yearly treatment means from the two locations.

Daily Hardlock Model

White cotton flowers were tagged with ribbon to indicate the date of bloom. Approximately 50 flowers were tagged on each day, and tagging generally occurred on one day per week during the period of bloom. This occurred at 4 locations in north Florida: Altha (2003, 2004), Jay (2003-2005), Marianna (2003-2005) and Quincy (2002-2005). After defoliation, tagged bolls were collected from the field. Hardlock was assessed based on the proportion of symptomatic locules to the total number of locules per boll. The mean hardlock rate was calculated for each day, and days with fewer than 10 bolls recovered were excluded from the data set.

Temperature and relative humidity were recorded at 15 minute intervals using a combination temperature and humidity sensor (model HMP45C, Campbell Scientific, Logan, UT). In one instance (Marianna, 2003) data were obtained from the Florida Automated Weather Network (FAWN).

Yearly Hardlock Model

Data from the control plots in Quincy described in the "Impact of Hardlock on yield" section above were utilized to construct a yearly model. In Marianna, insecticide plot data was substituted for control plot data as described in the Results.

Results

Impact of Hardlock on Yield

The impact of hardlock severity on yield was investigated in unsprayed control plots in Marianna (2003-2005, 2007) and Quincy (2002-2007), FL (Fig. 1A). Hardlock appeared to be the major yield-limiting factor in these years. It should be noted the crop was carefully managed and irrigated as needed, reducing the impact of other variables on yield. For comparison, the hardlock and yield values from the fungicide-treated plots are displayed (Fig. 1B). Fungicide applications frequently reduced hardlock and raised yields, possibly increasing the relative impact of other yield-determining factors in those plots.

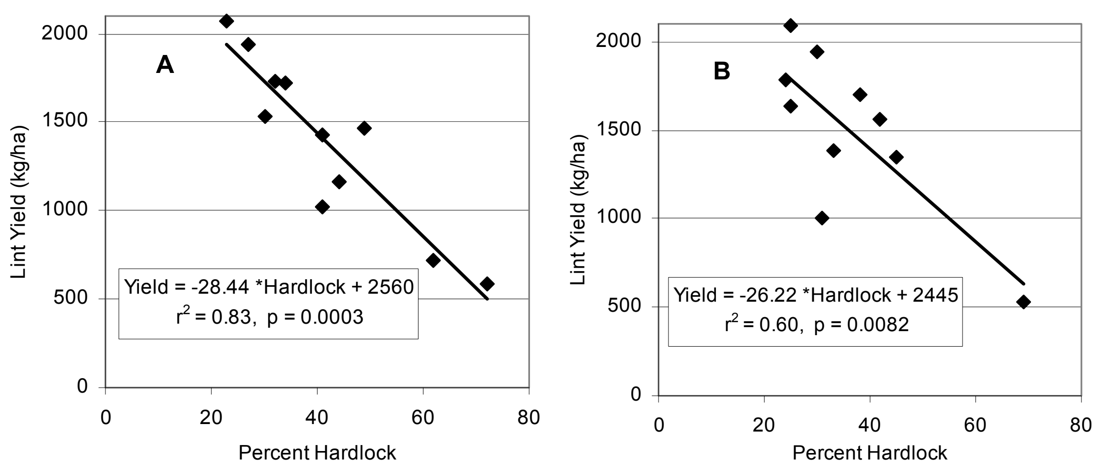

Figure 1. Impact of hardlock on yearly cotton yields in **(A)** unsprayed control plots and **(B)** fungicide-treated plots.

Daily Hardlock Model

Hourly temperature and relative humidity values were correlated to hardlock values for available days. When the data from all locations and years were grouped, significant correlations for temperature, but not relative humidity, were observed from 0000 to 0600 h on the day of bloom (data not shown). The mean temperature from 0000 to 0600 h was calculated for each day, and compared to the hardlock severity on the same day (Fig. 2). Excluding days outside the range of 21 to 25°C (approximately 15% of days in both the data set and in a typical season), showed a significant relationship between temperature and hardlock.

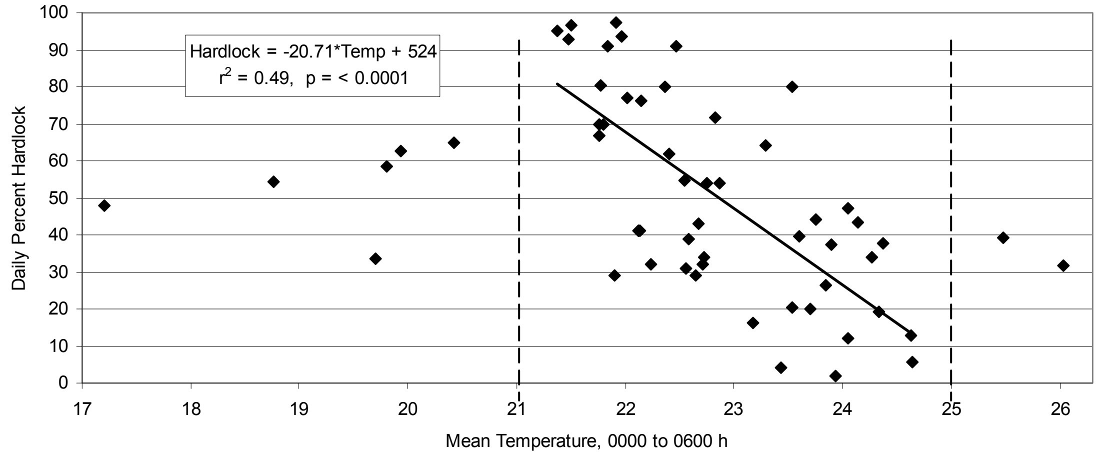

Figure 2. Influence of temperature on daily hardlock. Regression is limited to dates between 21 and 25°C.

Yearly Hardlock Model

The mean temperature between 0000 and 0600 h was calculated for each day of the assumed bloom period of July 1st to Sept. 1st to create a yearly mean. Data were available from Marianna and Quincy, FL. Regressions showed temperature to be associated with hardlock in Marianna (r^2 = 0.60, P = 0.2233, N=4, Hardlock = -25.79*Temp + 644.4) and Quincy (r^2 = 0.35, P = 0.1629, N=7, Hardlock = -14.39*Temp + 361.5). There were insufficient data points to attain significance at either location, so the data were lumped. A problem encountered was that the Marianna site had higher temperatures, but an equivalent amount of hardlock compared to Quincy. Conventional tillage was practiced at the Marianna site, while strip-tillage was used in Quincy. If fungal competitors to *F. verticillioides* are favored by the presence of surface residue and result in decreased inoculum production, this could explain the higher hardlock in Marianna relative to temperature. Data from Marianna insecticide-treated plots showed approximately the same yearly pattern as the unsprayed controls, but displayed lower levels of hardlock (data not shown). Insecticide plot data from Marianna were lumped with unsprayed control plot data from Quincy for analysis, providing a significant result (Fig. 2).

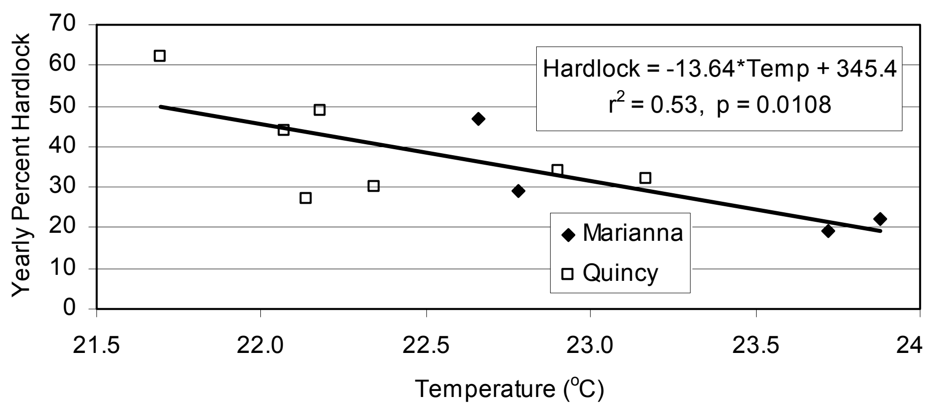

Figure 3. Influence of temperature on yearly hardlock.

Discussion

Forecasting models predict disease due to the effect on the pathogen (germination, growth and reproduction rates, etc.) or the host (plant stress, altered maturity rates). Cool night temperatures can delay anthesis (release of pollen from anthers) in cotton flowers by 2 to 3 hours (Oosterhuis and Jernstedt, 1999). On the first day of bloom, dissection of a flower reveals the style to be open, allowing the pollen germ tube to grow to the ovule. By the second day, this pathway is closed, making passage by pollen or possibly *F. verticillioides* much less likely. This closing of this pathway is probably results from pollination. If cool temperatures delay anthesis, and subsequently pollination, this would increase the period of susceptibility to infection by F. verticillioides. The difference in hardlock severity between both days and years could result from differing infection rates based on plant host susceptibility.

The possibility that tillage practices could reduce hardlock has not been explored. If more plant residue is present on the soil surface leading up to the time of bloom, it may increase the prevalence of competitors and antagonists of *F. verticillioides*. Sanders and Snow (1978) found the airborne spores of boll rotting pathogens increase for several weeks after 1st bloom, and hypothesized it was due to saprophytic growth on shed flowers and other plant parts. It is possible that by maintaining a more constant amount of residue throughout the season could lead to a more stable and balanced fungal community. Fernando et al. (2000) found more airborne conidia of *Fusarium graminearum* within 1.5 m of an infected wheat field than at 5 m, and this suggests local inoculum production may be important in the case of hardlock.

In this study, a strong relationship was noted between hardlock and yield ($r^2 = 0.83$) across years (Fig. 1A). This relationship was still fairly strong ($r^2 = 0.60$) in fungicide treated plots, and the data points were shifted closer to the high yield/low hardlock end of the distribution. Each 10 percentage point reduction in hardlock severity was associated with an increase of 284 (control) or 262 (fungicide treated) kg/ha of lint yield.

The effectiveness of hardlock management in previous studies has varied, depending on the severity of hardlock for the particular year. At hardlock rates of less than 30%, spraying is generally not effective, and this may occur in approximately 1 of 3 years in north Florida. The ability to forecast hardlock should allow control measures to be applied when most effective. An added benefit is that overall hardlock severity for the year could be estimated at the end of bloom, instead of after defoliation. Earlier knowledge of the expected impact of hardlock on final yields may be beneficial to producers.

Acknowledgements

This research was supported in part by cooperative research agreements with Cotton Incorporated, USDA/ARS, United Phosphorus, Inc and The State of Florida.

References

Fernando, W.G.D., J.D. Miller, W.L. Seaman, K. Seifert and T.C. Paulitz. 2000. Daily and seasonal dynamics of airborne spores of Fusarium graminearum and other Fusarium species sampled over wheat plots. Can. J. Bot./Rev. Can. Bot. 78(4): 497-505

Mailhot, D.J., J.J. Marois, and D.L. Wright. 2007. Influence of flower thrips on Fusarium hardlock severity. Plant Dis. 91:1423-1429.

Marois, J.J. and D.L. Wright. 2004. Etiology, epidemiology, and control of Fusarium hardlock of cotton in the southeast: the possibilities. p. 331-336. *In* Proc. Beltwide Cotton Prod. Res. Conf., San Antonio, TX. 5-9 Jan. 2004. Natl. Cotton Counc. Am., Memphis, TN.

Oosterhuis, D.M. and J. Jernstedt. 1999. Morphology and anatomy of the cotton plant. P.175-206. *In* Cotton: origin, history, technology, and production. C. Smith and J. Cothren (ed.).

Sanders, D.E. and J.P. Snow. 1978. Dispersal of airborne spores of boll-rotting fungi and the incidence of cotton boll rot. Phytopathology 68:1438-1441.

Srivastava, P., D. Mailhot, B. Leite, J. Marois and D. Wright. 2008. Monitoring the infection process of GFP-expressing *Fusarium verticillioides* in hardlock cotton. *In* Proc. Beltwide Cotton Prod. Res. Conf., Nashville, TN. 8-11 Jan. 2008. Natl. Cotton Counc. Am., Memphis, TN.

Willrich, M.M., B.R. Leonard, and G.B. Padgett. 2004. Influence of southern green stink bug, Nezara viridula L., on late-season yield losses in cotton, Gossypium hirsutum L. Environ. Entomol. 33:1095-1101.