Crop Protection 86 (2016) 56–61

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Cotton water-deficit stress, age, and cultivars as moderating factors of cotton fleahopper abundance and yield loss

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ARTICLE INFO

Article history:
Received 28 December 2015
Received in revised form
18 April 2016
Accepted 22 April 2016

Keywords:
Plant-insect interaction
Cotton insects
Gossypium hirsutum
Plant bugs
Water-deficit stress

ABSTRACT

Field experiments were conducted in 2012 and 2013 during drought conditions in South Texas and the Texas High Plains to test whether cotton water-deficit stress, age, and cultivars are moderating and interacting factors that affect cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter) (Hemiptera: Miridae), abundance and yield loss. Irrigation and sequential plantings of several cultivars were used to simulate a range of water stress, plant ages, and cultivar variability. Cotton grown under these experimental conditions were exposed to cotton fleahopper using natural and artificial infestation. Cotton cultivars had a strong influence on cotton fleahopper abundance, with higher densities on Stoneville cultivar 5458 B2RF, which is relatively pubescent, than on the Phytogen cultivar 367 WRF, which is relatively glabrous, in South Texas ($p < 0.04$). But the strong cultivar effects on cotton fleahopper abundance did not correspond to yield reduction. No water stress effects on cotton fleahopper densities were observed in 2012 ($p > 0.05$), whereas cotton fleahopper densities increased on older cotton grown under no water stress in 2013 in South Texas ($p < 0.05$). In contrast, yield response was primarily sensitive to soil moisture conditions (up to 50% yield reduction when grown in dryland mimic conditions below 75% crop ET replacement, $p < 0.0009$). Water and cotton fleahopper stress synergies were detected but variable, with greatest lint yield loss attributable to cotton fleahopper seen in cotton grown in high water stress conditions in the High Plains ($p < 0.05$). Yield trends were consistent across cultivars (no interaction with cultivar), even though cotton fleahopper populations varied significantly across cultivars and exceeded regional economic thresholds beginning the second week of squaring ($p < 0.05$).

1. Introduction

Cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter) (Hemiptera: Miridae), feeding on squares (i.e., pre-floral buds) of cotton, *Gossypium hirsutum* L. (Malvaceae), has reduced yield by up to 6% and also has delayed harvest in the southwest and mid-south (USA) cotton growing regions (Williams, 2000). But variability in the relationship of cotton fleahopper-induced square loss to subsequent yield loss under similar cotton fleahopper feeding pressure occurs and presents a challenge to cotton fleahopper management using traditional sampling and economic threshold methods (Ring et al., 1993; Brewer et al., 2012). In practice, field history of cotton fleahopper damage, weather conditions, and IPM practitioner sensitivity to square loss have been used to adjust decision-making locally. In South Texas, one to four foliar sprays for cotton fleahopper control are common across cotton fields that have apparently similar pest risk based on similar cotton fleahopper density estimates generated from pest monitoring (Brewer, pers. obs.).

In review of the literature, cotton yield loss variability to cotton fleahopper feeding has been partly associated with cultivar differences (Holtzer and Sterling, 1980), including heritable traits considered for plant resistance (Knutson et al., 2013; McLoud et al., 2016). Ring et al. (1993) calculated visual-based cotton fleahopper economic injury levels (EIL) of between 0.015 and 0.45 insects per plant. The wide range was attributed to cultivar influences, based on comparison of yield—cotton fleahopper density relationships. Parajulee et al. (2006) partly attributed severity of cotton square loss to susceptibility differences across stages of cotton development and age of the reproductive tissues when cotton fleahopper migrated into fields from overwintering sites. Cotton may also compensate for early square loss (Anon, 2015). Cotton water deficit-

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http://dx.doi.org/10.1016/j.cropro.2016.04.017

induced stress (water stress) also has been associated with square retention rates (Stewart and Sterling, 1989), which may influence plant sensitivity to cotton fleahopper feeding. These factors may be the underpinning of why thresholds in outreach materials vary across cotton growing regions of the southwest (i.e., 0.10 to 0.30 insects per terminal visually inspected during the first three weeks of squaring) (Anon, 2015), and why this insect is a minor pest in other locations (Williams, 2000). But if management strategies (i.e., planting time and cultivar selection) and weather conditions (i.e., poor rainfall in dryland production areas) influence cotton sensitivity to cotton fleahopper feeding, direct density estimation of cotton fleahopper for decision-making may give false indication of damage potential and improperly trigger insecticide applications using economic thresholds based on insect population estimates.

Therefore, square and subsequent yield loss variability has direct implications to in-season cotton fleahopper management that would benefit from further study. Here, we hypothesize that cotton water stress, age, and cultivars affect cotton fleahopper abundance and yield loss. As noted above, individual effects have been shown in past studies, but joint assessment of these factors may shed light on their comparative individual influences and their potential synergistic effects. The practical goal of understanding these relationships is to improve our assessment of cotton risk from cotton fleahopper and begin generation of a data base to make objective economic threshold adjustments under variable weather and management practices.

2. Methods

Drought conditions in Texas, 2012 and 2013, provided opportunity to assess cotton fleahopper activity and cotton response in a high contrast of water stress conditions manipulated by using irrigation in a field setting. Cotton fleahopper abundance and cotton response including yield were evaluated in several water regimes in two widely separated cotton growing regions: the coastal region of South Texas and the Texas High Plains. Standard agronomic practices were used (Morgan, 2015). Insect pest effects were largely restricted to cotton fleahoppers by using cotton cultivars with Bt-transgenes to control boll-feeding lepidopterans and by selecting study sites in areas where boll weevil has been eliminated and cotton fleahopper is a pest problem (Parajulee et al., 2006; Brewer et al., 2012; Luttrell et al., 2015). Cultivars, planting dates, and natural and artificial infestations of cotton fleahopper were used to optimize contrast in cotton fleahoppper pressure and cotton response. Experimental manipulation varied between South Texas and the Texas High Plains per opportunities and constraints outlined below.

2.1. South Texas location

A natural cotton fleahopper population was followed across time at a Corpus Christi, TX, location. Another plant bug, verde plant bug, that can affect square retention was detected during the study, but it never exceeded an economic threshold of 0.22 bugs per plant through peak bloom (Brewer et al., 2013). A split plot design was used to expose a natural population of cotton fleahopper to a soil moisture gradient of three (2012) and two (2013) water regimes (main plot), to two different plant ages by planting twice (sub-plot), and to two cotton cultivars (sub-sub-plot). An insecticide treatment was added as a final split plot in the design to directly test for cotton fleahopper-induced yield loss. Water regimes were established by using an above-ground drip irrigation system. Square injury from cotton fleahopper feeding was also confirmed by visual observation. The specific plot site was moved yearly so that the previous year crop was either sorghum or corn. There were five replications, and individual plot size was four 15.24 m rows on 96.5 cm centers.

In 2012, cumulative rainfall from planting to harvest was 15.5 cm for both plantings. The water regimes used were a high water stress dryland mimic using minimal irrigation (2.9 cm of irrigation, or 18.4 total water input with rainfall), a moderate water stress dryland mimic using irrigation targeting 75% crop evapotranspiration replacement (crop ET) (6.24 cm of irrigation, or 21.74 cm total water input with rainfall), and a light water stress mimic using irrigation targeting 90% crop ET (10.85 cm of irrigation, or 26.35 cm total water input with rainfall). The surface irrigation drip tubes were 17 mm (dia.) and emitted 3.4 L per h (Netafim, Fresno, CA). The two planting dates were April 12 and 30. The two cultivars were the early season maturing Phytogen 367 WRF (Dow AgroSciences, Indianapolis, IN) and the mid to full season maturing Stoneville 5458 B2RF (Bayer CropScience, Research Triangle Park, NC). The Stoneville cultivar was relatively pubescent or hairy to very hairy, a trait which has been associated with high cotton fleahopper populations (Knutson et al., 2013; Bourland et al., 2003), while the Phytogen cultivar was more glabrous or smooth to lightly hairy (Brewer, pers. obs., Bourland et al., 2003). The last split was a foliar insecticide treatment: no insecticide and acephate (Amvac Chemical, Newport Beach, CA) applied two times weekly at a rate of 560.4 g per ha beginning at second week of squaring.

In 2013, cumulative rainfall was 31.0 cm and 27.9 cm for the earlier and later planting, respectively, measured from planting to harvest. The two water regimes used were a moderate light water stress dryland mimic (15.49 cm of irrigation or 46.49 cm total water input with rainfall for an earlier planting, and 20.07 cm of irrigation or 47.97 cm total water input with rainfall for a later planting) and the non-water stress mimic using irrigation targeting 90% crop ET replacement (26.42 cm of irrigation or 57.42 cm total water input with rainfall for an earlier planting, and 35.05 cm of irrigation or 62.95 cm total water input with rainfall for a later planting). Comparing years, total water inputs doubled from the previous year due to the increased rains, but at planting soil moisture was more depleted in 2013 than in 2012. The two planting dates in 2013 were moved later this year (April 22 and May 6) to further encourage cotton fleahopper movement into the crop. The same cultivars were used as in 2012. The insecticide treatment was changed to thiamethoxam (Centric 40 WG, Syngenta Crop Protection, Greensboro, NC) applied four times weekly at a rate of 87.6 g per ha weekly beginning at second week of squaring.

2.2. High plains location

The Lamesa, TX, location experienced barely detectable cotton fleahopper populations in 2013 likely due to the extended drought; therefore we focused on boll retention and subsequent yield using an augmented population of cotton fleahopper. Water stress and cotton fleahopper pressure were each manipulated at two levels in a randomized complete block. Only trace amounts of rainfall were detected. A very high water stress dryland mimic (11.43 cm of irrigation/total water input) and a moderate water stress dryland mimic (22.86 cm of irrigation/total water input) were delivered through a low-energy precision application via center pivot irrigation system. For study site comparison, the total water inputs of the very high water stress here were nearly 50% lower than those of the high water stress level in the South Texas location in 2012, and the water inputs of the moderate water stress level here was similar to those of the moderate water stress in South Texas in 2012. An augmentative release of cotton fleahopper was used to directly test for yield response to cotton fleahopper as compared with a no infestation control. Square injury from cotton fleahopper feeding was also confirmed by visual observation. The cultivar planted was