THE EFFECTS OF PULSED WATER STRESS ON COTTON-PEST INTERACTIONS

W. B. Sconiers
M. D. Eubanks
Texas A&M University
College Station, TX
D. L. Rowland
University of Florida
Gainesville, FL

Abstract

Plant physiology is altered dramatically when plants are water stressed. Nitrogen (N) availability, digestible carbohydrates, and nutrients all change when plants are water limited and changes in the availability of these resources may affect insect herbivores. Currently, we are unable to accurately predict herbivore response to host water-deficit stress. The literature suggests contrasting responses for even the same herbivore type, such as piercing-sucking insects. Huberty and Denno (2004) conducted a meta-analysis of herbivore response and concluded that pulsed stress increases host plant quality for a variety of herbivores including thrips and aphids. They hypothesized that N availability was increased by water stress and that plant turgor increases when the plants recover from stress. The increased turgor pressure associated with plant recovery from stress allows herbivores to access the excess N. In this study, we examined the effects of pulsed and continuous stress on cotton (*Gossypium hirsutum*) physiology and herbivore abundance. Cotton physiology (i.e., photosynthesis rate, turgor pressure), defense compounds, and herbivore abundance were quantified on continuously stressed, pulse stressed, and non-stressed plants. Pulsed treated plants also hosted significantly more thrips and stinkbugs than continuous and non-stressed plants. This study will help us more accurately predict herbivore response to water stressed plants and provide insight into how water availability influences plant-insect interactions.

Introduction

Water stress alters the interactions between plants and insects by affecting the physiology of host plants. In 1969, T.C.R. White correlated water stress with outbreaks of psyllids (Hemiptera: Psyllidae) on eucalyptus trees in Australia with increased N concentrations in water stressed trees. The increased N in the water stressed trees was in the form of amino acids and proteins that plants use to alleviate the negative effects of stress. Thus, he proposed the “plant stress hypothesis” (PSH) which stated that herbivores may outbreak on water stressed plants due to these changes in plant physiology, primarily increased amounts of soluble N (White 1969, 1984; Mattson and Haack 1987; Waring and Price 1990; Huberty and Denno 2004). However since the formulation of the PSH, over a hundred studies have been conducted and they have produced mixed support for this hypothesis. For example, Waring and Price (1990) observed that gall midges (Diptera: Cecidomyiidae) had higher abundances on water stressed creosote plants (*Larrea tridenrutu*) compared to non-stressed plants. In contrast, Schowalter et al. (1999) found that gall midges did not prefer stressed creosote; in fact they highly preferred irrigated plants, the same plant species these gall midges preferred under stress in the Waring and Price (1990) study. Archer et al. (1995) found greater densities of aphids on water stressed wheat plants, but Larsson and Bjorkman (1993) found that aphid densities were not significantly higher while on stressed Norway spruce. This variation in herbivore response makes it difficult to accurately predict herbivore abundance on water stressed plants. Therefore Huberty and Denno in 2004 conducted a meta-analysis of 82 published studies in this field to find the source of the variation. They found that the variation in herbivore response was primarily due to researchers employing different types of water stress, leading to different physiological changes in plants and therefore different responses from herbivores. The first type of water stress was “continuous stress”, in which plants did not receive water for the duration of the study. This results in the constant decline in turgor pressure and water availability in plants, reducing herbivore access to increases in N concentration due to water stress. The second type of water stress is “pulsed stress” in which water is returned to experimental plants, initiating periods of stress recovery. Pulsed stress allows the N containing compounds to be accessed by herbivores by providing periods of increased water content. Turgor pressure is important primarily for piercing sucking herbivores, aphids for example, that require the outward water pressure from plants to extract phloem (Wearing 1972). Huberty and Denno also found that the majority of studies that supported the plant stress hypothesis were studies that employed pulsed stress. Therefore, Huberty and Denno proposed the “pulsed stress hypothesis” which stated that herbivores will respond positively to pulsed stress plants since these plants have the turgor pressure necessary for herbivores to access stress-induced increases in nutrients. In this study, we induced continuous and pulsed water stress in cotton plants and observed changes in cotton physiology and herbivore response. The objectives of this study were to clearly differentiate the effects of both types of water stress on cotton physiology and herbivore response. We hypothesized that herbivores will be more abundant on pulsed stress plants compared to continuously stressed plants This study is significant in that not only does it clarify herbivore response to water stressed plants, but may also be used to predict pest activity and abundance on field crops, leading to improved pest management practices.

Methods

We conducted two 10 week (plus 1 pre-treatment week) water-deficit field experiments at the Texas A&M Field Laboratory in Burleson County, TX. Commercial cotton (*Gossypium hirsutum* L.), Delta Pine 174RR Flex was used and does not contain drought resistant or sensitive characteristics, and does not contain the Bt gene for herbivore resistance. The cotton was planted on May 3rd, 2010 (Season 1) with the pre-treatment week starting on June 14th 2010 and planted on April 18th, 2011 (Season 2) with the pre-treatment week starting June 13th, 2011. We had 0.6 hectares of experimental cotton divided into 3 treatments: continuous water stress, pulsed water stress, and control non-stress treatment. The hectares were divided into 54 6x4.5m plots, spread into 9 blocks, with each treatment having 3 blocks randomly placed throughout the field, for a total of 18 plots per treatment and a random complete block design. Experimental blocks had 9.1m of buffer zone cotton on all sides. Each block of 6 plots was separated from adjacent blocks by 3 rows and with 2.7m of cotton between plots in each block to provide a buffer region between blocks and plots. The cotton was furrow irrigated during the same time of the week for control and pulsed stress treatments. The continuous stress treatment did not receive irrigation, but was only allowed to receive ambient rainfall. The control treatment was watered weekly to ensure non-stress conditions. For the pulse treatment, we used a pressure chamber instrument (PMS Instrument Co. model 615) to determine plant turgor pressure. A turgor pressure reading of -1.2 Mpa (-12 bars) indicates that plants are water stressed and are accumulating osmolytes (Hsiao 1973; Lombardini 2006). Once turgor pressure indicated that plants were under stress, we provided irrigation to induce turgor recovery to return pulse stressed plants to non-stress levels. All measurements were taken once a week starting from the pre-treatment week to week 10, sampled plants were randomly chosen.

Arthropod surveys were conducted to quantify the species and abundance of arthropods present in experimental plots. This was done by beating arthropods off of plants into a bowl and surveying the top 0.61m of each plant for any arthropods that were not dislodged (Bohmfalk et al. 2011 revision). Five randomly chosen plants were surveyed per plot during the same time of the day and week. Arthropods were field or lab identified. Results were analyzed using repeated measures ANOVA.

Results

Herbivore response to experimental plants differed based on treatment, especially for thrips, stinkbugs, and piercing-sucking herbivores as a group. In 2010, thrips exhibited similar abundances on control and continuously stressed plants with approximately 1 thrips per sampled area on the plant for the duration of the study. Pulse stressed plants had up to 7 thrips present per sample area, starting with the initiation of stress recovery starting at week 5, with approximately 2 thrips prior ($p<0.0001$, $F_{14, 255}=22.086$, time G-G ε, $p<0.0001$, time*treatment G-G ε, $p<0.0001$, Figure 1.) Stinkbugs exhibited a similar response as well in 2010, with an increase from 0.1 stinkbugs per sampled area prior to stress recovery to 0.32 stinkbugs during recovery. The control and continuous stressed plants remained the same with a range from 0.04 to 0.15 stinkbugs per sampled area ($p<0.0001$, $F_{14, 255}=4.2910$, time G-G ε, $p<0.0001$, time*treatment G-G ε, $p=0.0100$, Figure 2.) During the 2011 season, we found that stress severity directly influenced the abundance of piercing-sucking herbivores. The control treatment had the most with 35 herbivores per sampled area, followed by pulsed stress plants with 30, and continuous with 10 ($p=0.0085$, $F_{2, 30}=5.6145$, Figure 3.) The difference between the control and pulse abundances was not significant.

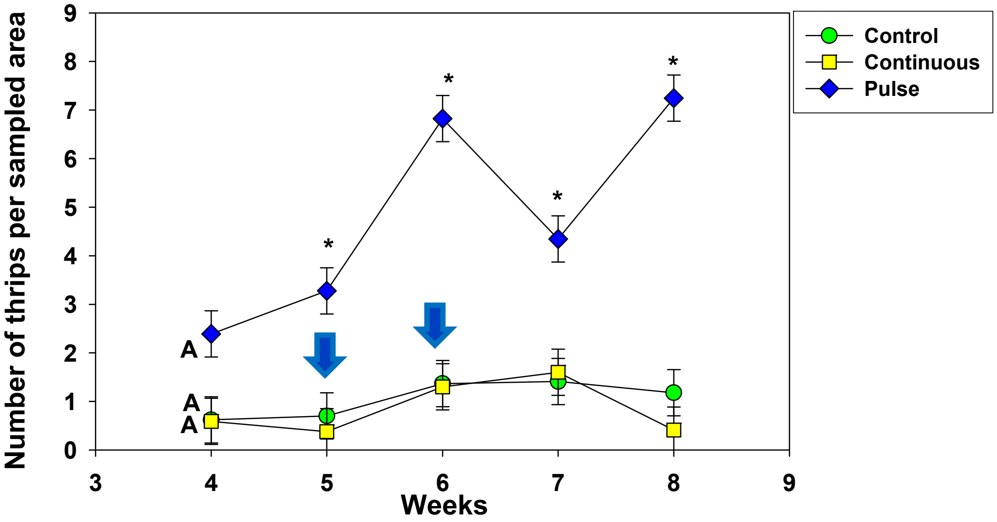

Figure 1. Thrips abundance on continuous and pulsed stressed plants. At week 4 prior to pulse recovery starting at week 5, the pulse stressed plants had 1 more thrips per sampled area than the other treatments, however the "A"s signify that the difference was not significant. The "*" indicate that the abundance of thrips for the pulse treatment was different than that of the other two treatments for that respective week. $p<0.0001$, $F_{14, 255}=22.086$, time G-G ε, $p<0.0001$, time*treatment G-G ε, $p<0.0001$. The arrows indicate the weeks where irrigation was applied to pulse stressed plants.

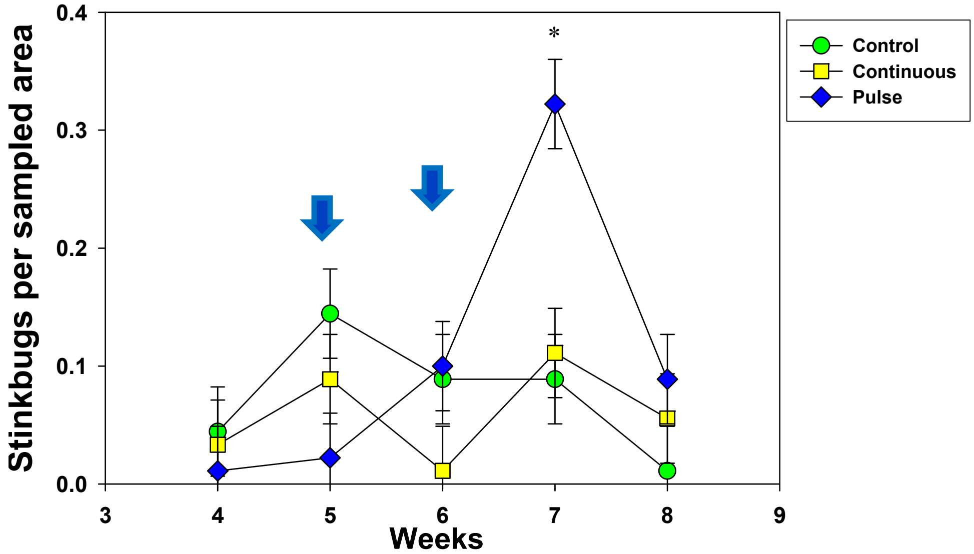

Figure 2. Stinkbug abundance on continuous and pulsed stressed plants. Irrigation during week 6 led to an increase in stinkbug abundance from 0.1 stinkbugs per sampled area to 0.32 versus the continuous stress and control plants that did not have more than 0.15 stinkbugs per sampled area. $p<0.0001$, $F_{14, 255}=4.2910$, time G-G ε, $p<0.0001$, time*treatment G-G ε, $p=0.0100$. The arrows indicate the weeks where irrigation was applied to pulse stressed plants.

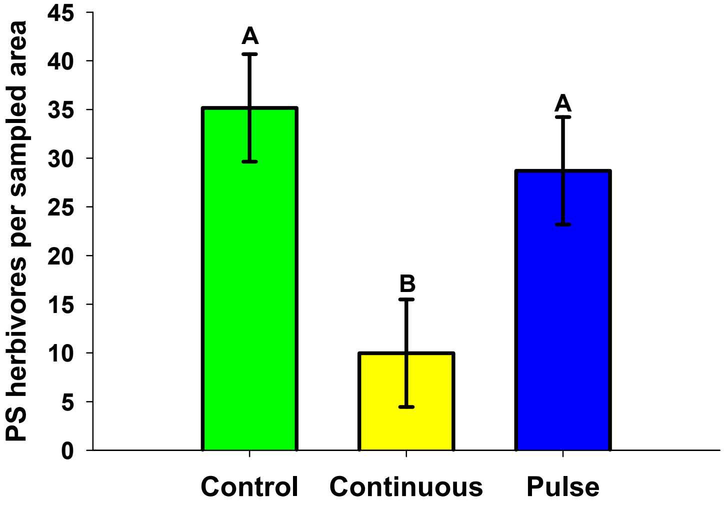

Figure 3. The summative amount of piercing-sucking (PS) herbivores per sampled area for each treatment throughout the entire 2011 season. Control and pulse stressed plants have statistically similar amounts of piercing-sucking herbivores with 35 and 29 herbivores, while the continuously stressed plants did not with 10 herbivores ($p=0.0085$, $F_{2,30}=5.6145$). Bars with different letters are significantly different.

Summary

We found that pulse stressed plants had more pests during periods of stress recovery than continuously stressed plants and are similar to non-stressed abundances. Continuous and pulse stressed plants each elicit a different response in herbivores. Continuous stress had a negative effect on herbivore abundance, with cotton plants under continuous stress having fewer herbivores than control plants. Control plants had the most piercing-sucking herbivores overall, but pulse stressed plants had up to 7 times more thrips and 3 times more stinkbugs during periods of stress recovery. This means that stressed cotton will be expected to have greater numbers of pests when water returns. It may therefore be possible to predict when peak abundances of herbivores will be present during a growing season to more efficiently control pests and reduce pesticide use.

Literature Sited

Archer, T. L., E. D. Bynum, A. B. Onken, and C. W. Wendt. 1995. Influence of water and nitrogen fertilizer on biology of the Russian wheat aphid (Homoptera: Aphididae) on wheat. Crop Protection **14**:165-169.

Bohmfalk, G.T., Frisbie, R.E., Sterling, W.L., Metzer, R.B., and Knutson, A.E. 2011. Identification, biology and sampling of cotton insects. Texas A&M University System http://www.soilcropandmore.info/crops/CottonInformation/insect/B-933/b-933.htm

Hsiao, T. C. 1973. Plant Responses to Water Stress. Ann Rev. Plant Physiol. **24**:519-570.

Huberty, A. F. and R. F. Denno. 2004. Plant Water Stress and Its Consequences for Herbivorous Insects: A New Synthesis. Ecology **85**:1383-1398.

Larsson, S. and C. Bjorkman. 1993. Performance of Chewing and Phloem-feeding Insects on Stressed Trees. Scandinavian Journal of Forest Research **8**:550-559.

Lombardini, L. 2006. Ecophysiology of Plants in Dry Environments Dryland Ecohydrology. Pages 47-65 *in* P. D'Odorico and A. Porporato, editors. Springer Netherlands.

Mattson, W. J. and R. A. Haack. 1987. The Role of Drought in Outbreaks of Plant-Eating Insects. BioScience **37**:110-118.

Schowalter, T. D., D. C. Lightfoot, and W. G. Whitford. 1999. Diversity of Arthropod Responses to Host-plant Water Stress in a Desert Ecosystem in Southern New Mexico. The American Midland Naturalist **142**:281-290.

Waring, G. L. and P. W. Price. 1990. Plant water stress and gall formation (Cecidomyiidae: Asphondylia spp.) on creosote bush. Ecological Entomology **15**:87-95.

Wearing, C. H. 1972. Responses of Myzus Persicae and Brevicoryne Brassicae to Leaf Age and Water Stress in Brussels Sprouts Grown in Pots. Entomologia Experimentalis et Applicata **15**:61-80.

White, T. C. R. 1969. An Index to Measure Weather-Induced Stress of Trees Associated With Outbreaks of Psyllids in Australia. Ecology **50**:905-909.

White, T. C. R. 1984. The abundance of invertebrate herbivores in relation to the availability of nitrogen in stressed food plants. Oecologia **63**:90-105.