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DEVELOPMENTAL RESPONSES OF COTTON GENOTYPES AS AFFECTED BY WATER APPLICATION REGIMES

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Abstract

Water stress has two primary effects on cotton development depending on when it occurs and its intensity. Stress prior to flowering usually restricts the number of fruiting sites whereas, stress during early boll development results in fruit abortion. Field experiments were conducted using varying frequencies of applications and volumes of water to determine their effects on the developmental processes of cotton (*Gossypium hirsutum*, L.) cultivars differing in degrees of indeterminacy. This was a two-variable experiment with one regime designed to deliver different volume applications of 3, 4, and 5 gallons per minute per acre, delivered on a constant 6-day frequency. The second regime was designed to create stress and recovery cycles by delivering water at a fixed volume over 3, 6, 9 and 12-day irrigation intervals. Comparisons of the effects of these regimes on plant height, main stem node production, production of fruiting sites and percent of fruit retention revealed genotypic differences in response to water volume and frequency regimes in all developmental categories evaluated. The more determinate-like cultivars were more sensitive to production of nodes and fruiting sites under water stress, while the more indeterminate type cultivars showed greater sensitivity to water stress during fruit development, which affected fruit retention.

Introduction

In most areas of the United States, water is the most limiting factor in growth and development of cotton plants. In the major cotton producing regions of Texas, the opportunity for short-term water stress is great as a result of high growing season temperatures and extended periods between rainfall events. Due to the indeterminate growth habit of the cotton plant, the effects of this short-term stress are easily quantifiable at distinct stages of development. It is the major consensus among researchers that root tips are the sensing sites for water stress in plants. One prevailing theory is that root tips sense stress and transmit a hormonal "signal" to the shoot where developmental processes are affected. McMichael (1986) investigated how the changes in water content of the soil affect the growth and productivity of plant tops via changes that occur in absorption of water by plant roots. These studies indicate the distribution of cotton roots may be altered by changes in soil water content as the soil dries out, and there is some indication that gradual changes in soil water status may or may not impact top growth by allowing the root systems to adapt to the changing environment. It is well established that these root-shoot relations directly affect the development and morphology of plants. Davies *et.al.* emphasized the importance of the role of plant roots in sensing the amount of water in the soil by observing that the variation in shoot physiology can often be linked more closely to changes in soil water status than to changes in leaf water status. They suggested that plants must "sense" the drying of the soil around the root and communicate the information to the shoot by some means other than a reduction in the flux of water to the shoots (Davies and Zhang, 1991). Other recent studies cited by Davies suggest that this detection mechanism involves the transfer of chemical, presumably hormonal, information from roots to shoots (Cowan, 1982; Jones, 1980). One commonly held theory is that hormones such as abscisic acid (ABA) and cytokinins are playing a major role in stomatal closure and, thereby, may be responsible for the regulation of physiological and developmental processes when plants sense stress. Zeevaart, *et. al.* (1988) observed that during vegetative growth, endogenous levels of ABA increase in response to water stress conditions, and ABA is an essential mediator in triggering the plant responses to adverse environmental stimuli. This study is being conducted to identify how water stress affects root tip distribution, the relatedness of root sensing mechanisms to production and retention of fruit and, ultimately, attempt to determine the hormonal mechanism by which these responses are thought to occur. However, our initial goal was to determine to what extent water stress contributes to changes in development.

Materials and Methods

The study was conducted for two years (2000 and 2001) on the Texas Tech University Crop Production Facility in Brownfield, Texas. Six varieties of cotton, 3 picker-types (DPL 90, SureGrow 521, DPL 2156) and 3 stripper-types (PM 2326, PM 2200, and PM2145) were selected for degree of indeterminacy. Seed were planted in 32-inch rows under two variable water delivery systems. A surface drip system was constructed of drip tape stretched the length of every second furrow. This system was operated manually to create stress and recovery cycles of 3-day, 6-day, 9-day and 12-day durations.

The 3-day treatment received .75"/acre of water per cycle, the 6-day treatment received 1.5"/acre, the 9-day treatment received 2.25"/acre, while 3"/acre was delivered to the 12-day treatment for each cycling period. Identical varieties were planted under a center pivot LEPA irrigation system with drop hoses in every second furrow that delivered variable volumes of 3 GPM, 4 GPM and 5 GPM at a constant 6-day frequency. One repetition of the six varieties was grown under dry conditions. At 60, 80 and 100 days after planting, 10 plants from each treatment were randomly selected for sampling. Each plant was cut at the cotyledonary node and a sample of each hypocotyl segment was retained for hormone analysis. Plants were hand mapped for plant height, number of fruiting branches, node number, total fruiting sites and abscised sites. Plant mapping data was analyzed for averages at each developmental category and percent retention of fruiting sites was obtained using PMAP software. Due to high losses from insect pressure (beet army worms) in 2000, results from the 2001 study were used exclusively for the purposes of this paper.

Summary

The frequency regimes were designed to produce a continuum of stress and recovery intervals. The 3 and 6-day frequencies induced little to no stress, the 9 and 12-day cycles created moderate to severe stress, while the dry regime induced maximum stress. The volume treatments allowed for a constant supply of water at differing volumes thus allowing for slowly developing, continuous stress at low volume applications absent the recovery cycles. Analysis of development of plant height, main stem node number and production and retention of fruiting sites revealed genotypic differences in response to the water volume and frequency regimes in all developmental categories evaluated. Specifically, the determinate cultivars were especially sensitive to main stem node development and total number of fruiting sites at the lower volume applications. Indeterminate cultivars exhibited a higher stress response to the percentage of fruit retention with the variations in water frequency application. Further research into the relative concentrations of the hormones ABA and cytokinin present in the transpiration stream prior to and immediately following stress cycles may shed some light on the reasons for the variable responses we noted in this preliminary analysis.

References

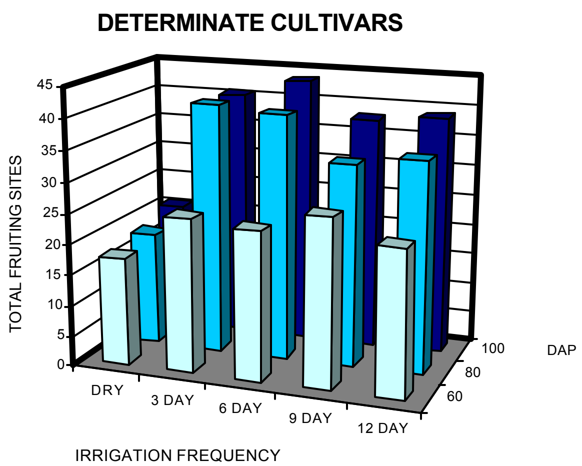
Cowan, I.R. 1982. Regulation of water use in relation to carbon gain in higher plants. Physiological Plant Ecology II. O.L. Lange, P.S. Novel, C.B. Osmond, H. Ziegler (eds.). Berlin: Springer-Verlag. p. 589-614.

Davies, W.J. and Zhang, J. 1991. Annu. Rev. Plant Physiol. Plant Mol. Biol. 42:55-76.

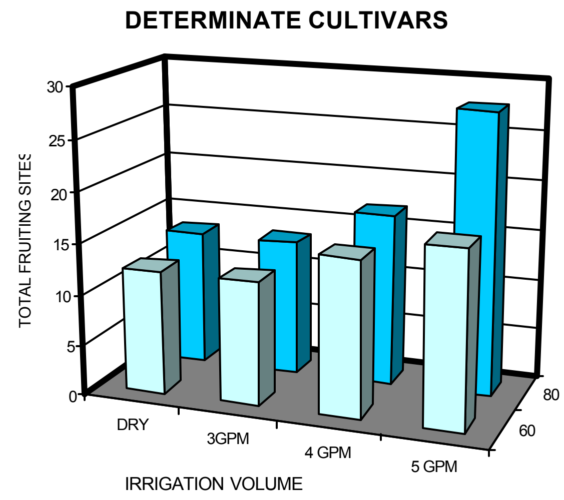
Jones, H.G. 1980. Interaction and integration of adaptive responses to water stress: the implications of an unpredictable environment. In: Adaptation of Plants to Water and High Temperature Stress. N.C. Turner, P.J. Kramer (eds.). New York: Wiley. p. 353-365.

McMichael, B.L. 1986. Growth of roots. Cotton Physiology Number One: The Cotton Foundation Reference Book Series. J.R. Mauney and J. McD. Stewart (eds.). p. 29-38.

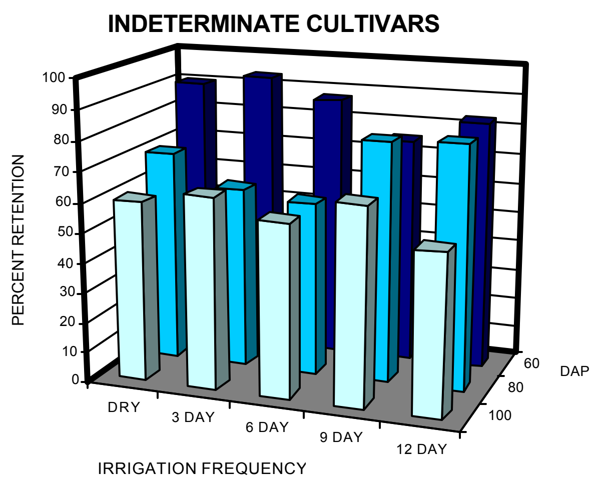
Zeevaart JAD, Creelman RA. 1988. Metabolism and physiology of abscisic acid. Annu. Rev. Plant Physiol. Plant Mol. Biol. 39:439-473.



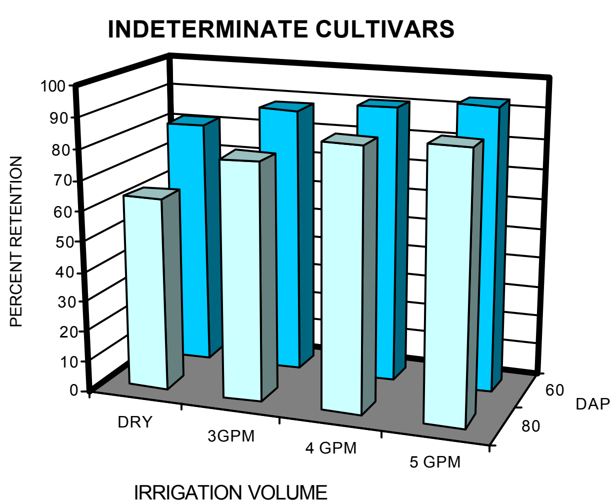
Graph 1. Total Fruiting Sites by Irrigation Frequency.



Graph 2. Total Fruiting Sites by Irrigation Volume.



Graph 3. Percent Retention by Irrigation Frequency.



Graph 4. Percent Retention by Irrigation Volume.