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High Temperature Effects on Cotton

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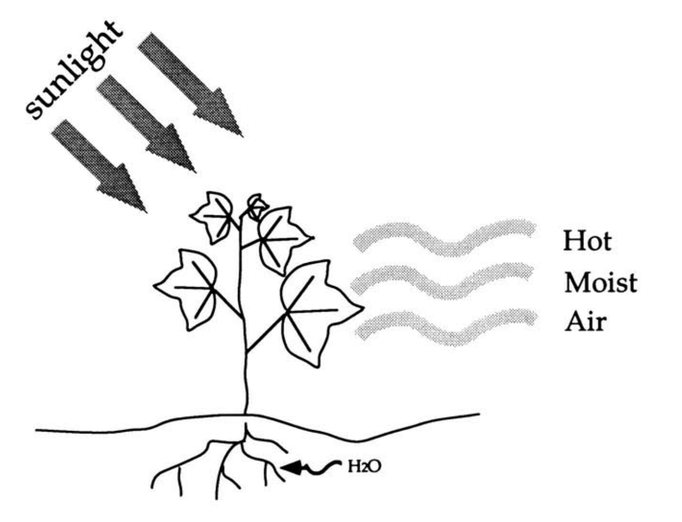
Cotton yields and quality skyrocket or plummet in response to weekly changes in temperature. This is particularly true for dry-land cotton where hot temperatures mean high water use with little rainfall. But even in irrigated areas the yield and quality is closely related to temperature. Despite our inability to alter rainfall and air temperature, producers can benefit from an understanding of the effect drought and heat have on their crop. We don't have to wait 2 weeks after a heat spell to see the impact of high temperatures in the field. We can predict fairly precisely the effect of hot temperatures during each growth stage on yield and quality. In this issue of Cotton Physiology Today we will discuss the effects of high temperature on cotton and hopefully allow you to better anticipate what a heat spell will do to a specific field so that timely adjustments in production practices can be made.

What is Hot

Much of the confusion regarding high temperature and its effect on cotton growth derives from the many factors that determine how hot the plant tissue actually gets. Air temperature is important, but so also are sunlight, soil moisture, relative humidity, and air movement. Plants attempt to regulate their tissue temperature, just like warm blooded animals. Although cotton can only cool itself, not heat itself. Cotton attempts to keeps its plant tissue temperature between 74 and 90, in the optimum range for growth and photosynthesis. It accomplishes this by opening stomates in the leaves allowing water to evaporate when the air temperature and sunlight heats up the plant. Thus during a hot dry afternoon, well-watered cotton plants are often 10 degrees cooler than the air temperature. Under the extremely hot June 1990 weather in Arizona, where the air temperature reached 121°F, plant canopy temperatures of 88°F were measured in well watered cotton fields. At the same time, canopy temperatures in less than well watered fields reached 104°F, which certainly was not favorable for carbohydrate production. Over 99.9% of the water taken up by plants is used to evaporatively cool the plant. The evaporative cooling in one acre of July cotton provides the same cooling as 50 to 100 typical home air conditioners.

Components That Regulate Plant Temperature



The diagram to the left illustrates the components that regulate plant tissue temperature. We see that drought and hot weather work together to damage the plant primarily from high tissue temperature and not tissue desiccation. The following conditions restrict cottons ability to cool itself causing high temperature damage:

- Dry soil restricts the flow of water into the plant and out the leaves. The actual soil water content is less important than the ability of the soil to conduct or move water into the plant. Cotton growing in sandy soils will often wilt during the afternoon, despite good soil moisture, due to the poor movement of water in sandy soils after they have drained.
- High relative humidity will restrict evaporative cooling because the air is near saturation and can only hold so much water at that temperature. When high humidity occurs in combination with bright sunlight, well-watered cotton tissue temperature can often exceed air temperature by 3-4°F.
- Bright sunny days increase plant tissue temperature because cotton is a strong absorber of solar radiation. Drought adapted plants often have a white waxy surface that reflects sunlight, but cotton has a high absorptivity of light. When a cloud passes overhead cotton tissue temperature may drop by 5°F
- High night temperatures increase plant temperature because the cotton closes its stomates and ceases evaporative cooling when the sun sets. At night the only source of evaporative cooling is from a moist soil surface, or free water on the plant from a recent rain or sprinkle irrigation.

Also in this issue

- Vascular diseases such as Fusarium or Verticillium wilt increase leaf temperature because the water conducting system in the stem is blocked. Even though the roots are adequately moist, the leaves fed by the blocked conducting system will be heat damaged from lack of evaporative cooling.

Effect of High Temperature — Physiology

Living organisms, such as plants, contain individual sacks of chemical soup, called cells. The chemicals in this soup combine and rearrange to support growth and maintain their organized state. Temperature is the driving force that allows the chemicals in this soup to react. The warmer the temperature the faster they react, until the temperature gets so warm that the cells start to leak and basic materials such as enzymes start to degrade.

This effect of temperature on speeding up chemical reactions is beneficial during the day because photosynthesis and growth is faster. But when those same daytime temperatures persist into the night, they cause the plant to burn up stored energy just to maintain its organized structure. Respiration is increased. Since the plant is also unable to cool itself during the night, high night temperatures are detrimental regardless of dry-land or irrigated cotton. When high night temperatures (minimum above 80°F) coincide with peak bloom, the plant sheds many of its small bolls. During peak bloom the demand for carbohydrates to fill developing bolls is high, and increased night temperatures drain carbohydrates due to high night respiration. The plant responds to the carbohydrate shortage by setting fewer seeds per boll and shedding small bolls. Four to five days after a heat wave starts, cotton plants in mid to late bloom will shed small bolls, which are the most sensitive stage to environmental shed. As the duration of high temperature stress extends, larger and larger bolls will be shed.

When the night temperatures remain in the mid 80's another detrimental effect occurs — pollen sterility. During early square development pollen grains undergo a temperature-sensitive stage. Since this stage occurs 2 to 3 weeks prior to bloom, we observe the impact of pollen sterility 17 to 19 days after the occurence of high night temperatures. The visual impact of pollen sterility is anther sacks that remain smooth and fail to shed pollen, while the physiological effect is a dramatic reduction in boll set. Pima cotton is very sensitive to pollen sterility. Upland cottons are less sensitive but still do suffer reduced fruit set in hot growing seasons.

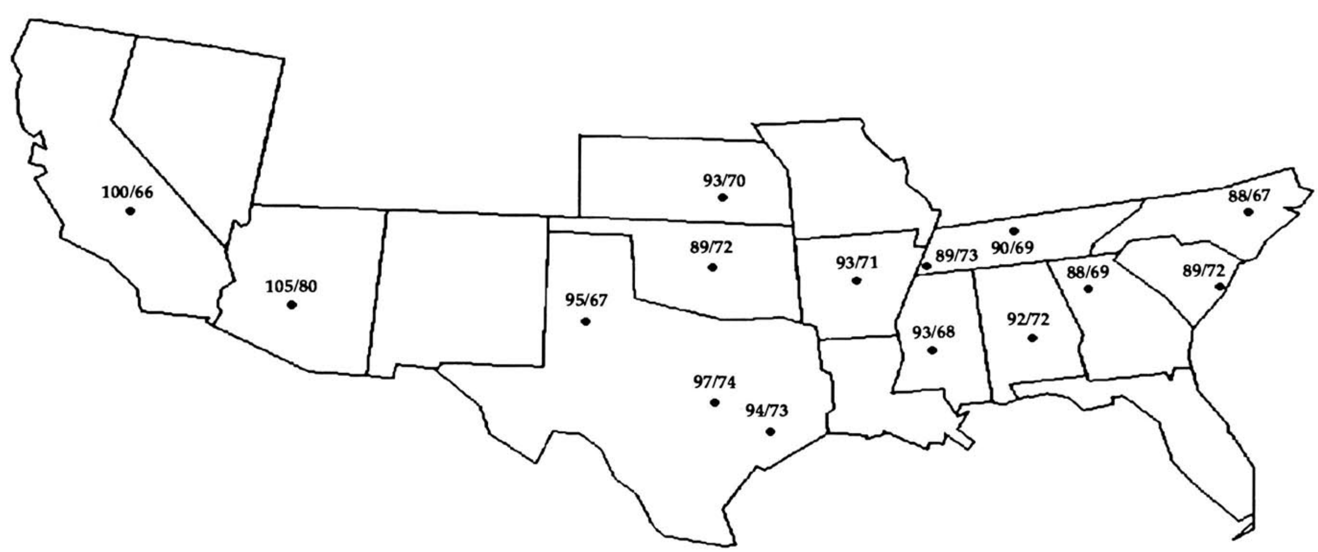
Effect of High Temperature — Yield

Whether high daytime temperature increases or decreases yield depends on the availability of soil moisture and the stage of crop development. When the maximum air temperatures are near 100, it's a good bet that most of the daylight hours are favorable for rapid growth (90 to 95°F air and 85°F plant temperature), if the plant has sufficient moisture to cool itself. Work in Arizona indicates that maximum day temperatures in excess of 105°F continue to increase yields of well-watered cotton.

An optimum range in air temperatures of 77°F to 113°F has been determined for cotton photosynthesis, with photosynthesis dropping to zero at 131°F. The wide range in tolerable temperatures gives well watered cotton the capacity to live and function under very high temperatures. This is probably one of the benefits derived from cotton having originated in hot, tropical climates.

Without adequate moisture, high air temperatures during the day have the inverse effect; they decrease yield. The damaging effect is most severe on cotton in bloom. Respiration of "hot" cotton is dramatically increased while photosynthesis is decreased, causing a

Average Daily Maximum and Minimum Cotton Belt Temperatures for July



severe shortage of carbohydrates which limits the plant's ability to fill bolls. The plant responds to this "carbohydrate squeeze" by adjusting the boll load (a polite way of saying that the crop goes to hell in a hand basket). High temperatures combined with water stress results in boll shed, small boll size and leaf damage. Additionally the leaf damage or premature senescence will cause the plant to cutout early and not set a top crop.

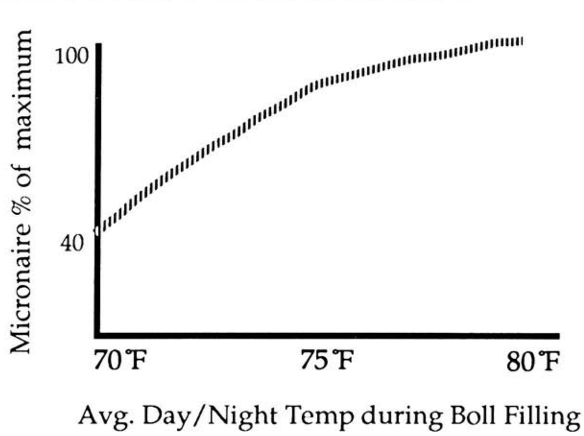
When hot temperatures occur prior to bloom or after boll set, yield is often increased. Hot temperatures prebloom speed the arrival of the bloom period and occur at a time when water use is low and the root system is still expanding into fresh soil moisture. Hot temperatures after boll set hasten the maturation and opening of the crop.

High night temperatures are detrimental to young boll set and boll size regardless of the moisture status, because the plant does not cool itself at night. Minimum night temperatures in the 80's decrease yield due to the high respiration and reduced supply of carbohydates, resulting in the same "adjustment of boll load" discussed above.

Effect of High Temperature — Quality

Quality is much less sensitive to high temperatures than yield. In general, cotton growing in a hot climate will have a higher micronaire due to the thicker rings of cellulose that are deposited daily in the fiber. Cotton fiber needs a minimum of 40 to 50 days to mature regardless of temperature. The boll period is less accelerated by hot weather than other developmental stages, such as seedling growth. Under hot weather, especially if the plant is adequately watered, each daily ring will be thicker resulting in thick fibers and increased micronaire. Additionally, hot temperatures often cut short the boll-setting period, decreasing late-set bolls that tend to have lower micronaire. Field data from the Texas High Plains relates the average day/night temperature during the boll development period to the cotton crops micronaire.

Effect of Boll Development Temp on Micronaire



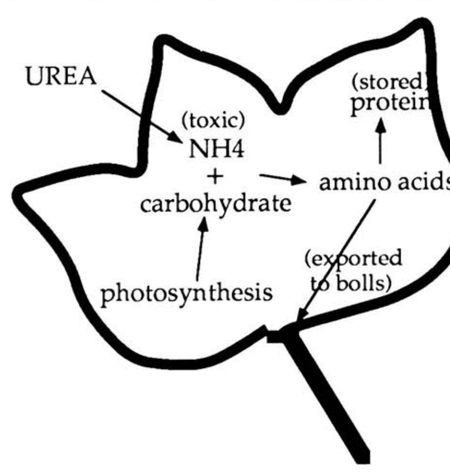
(Wanjura 1985)

Part of the reason that quality is less sensitive to stress than yield is the plant's "adjustment in boll load" discussed above. The plant retains only the number of bolls that it currently has carbohydrate supply to mature. But if the development of stress is rapid and severe, cotton will not have time to shed all the bolls and some crop will be left on the plant. Depending on its maturity stage, some of these bolls may open and will be of radically inferior quality. These bolls will have fiber quality similar to a premature defoliation: reduced micronaire, strength and possible length.

Managing Cotton During a Drought

When dry-land cotton is wilted with no forecast of rain there is little we can do to remedy the situation, but there are certain practices that should be avoided. Cultivations that damage roots can aggravate plant stress and increase shed. Even shallow cultivations, when the soil is dry, can break roots at a deeper depth. Plant Growht Regulators such as PIX should not be applied to water stressed cotton. If needed, application should be delayed till after a rain or irrigation. Foliar fertilizers such as urea should also be avoided in water-stressed cotton. For the plant to utilize foliar urea it must have sufficient carbohydrates to detoxify the internal ammonia that occurs when urea is absorbed into the leaf. When carbohydate levels are low, such as with a water-stressed crop with a boll load, foliar urea can damage and burn the leaves.

Nitrogen Conversions with Foliar Urea



Managing Cotton During High Temperatures

Where irrigation is available the management of cotton during high temperatures is summed up by "frequent light irrigations." Keep the availability of soil moisture high and the surface soil moist. Avoid heavy irrigations that saturate the soil and cause anaerobic (lack of oxygen) stress, because cotton will wilt and die rapidly in warm waterlogged conditions.

Cotton will use more water during a hot dry day than a cool or humid day. The average daily water use in July is 50% higher for Arizona cotton than for Mississippi cotton. Under high temperatures, the maintenance of good plant water relations becomes extremely important. If irrigated fields are allowed to reach an excessive level of stress the plant's ability to hold bolls is dramatically decreased. Mainstem growth will also be reduced, resulting in less future leaf and square production. Additionally leaf size will be limited and existing leaves will prematurely age or senesce. All of these effects reduce the plant's ability to set and mature bolls and creates a plant that cuts out early and yields less than its well-watered counterpart.

Fruit retention and boll size should be closely monitored during and after hot weather. This is because irrigated cotton can grow rapidly when conditions are favorable for growth but bolls are shedding or small. Irrigated cotton in hot weather can often get excessively tall and require a plant growth regulator to slow vegetative growth. During or after a heat wave it is vastly better to control growth with a PGR than to utilize water stress. Both methods will control height but only one will keep fruit on the plant.

Although cotton is tolerant of high temperatures and drought, the plant can only set and mature a respectable yield when water is available for the plant to cool itself down to the optimum tissue temperature of 85 to 90°F.

About the Authors

Jeff Silvertooth is the Cotton Specialist for the University of Arizona, home state for temperatures over 120°F. Jeff's research focuses on agronomic decisions in both Pima and Upland cotton. Recent emphasis has been on plant nutrition and nutrient management in irrigated cotton systems.

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