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Environmental Causes of Shed

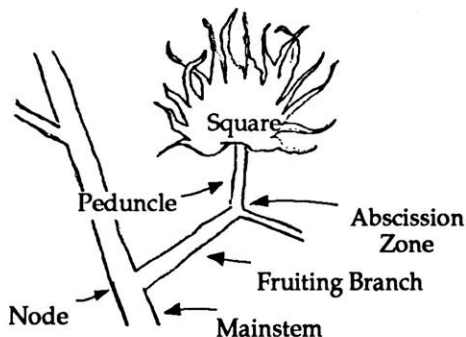
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Introduction

Square and boll retention is a season long job for growers across the Cotton Belt. No growing region escapes all of the factors that cause square and boll abscission. If it isn't insects or disease causing shed, it's weather or plant conditions. In this article we will examine the more important weather or plant related causes of abscission, and discuss why we can't retain all the squares even when free of pests. We'll start with a discussion of the abscission process, then proceed into various environmental causes of abscission and conclude with a discussion of how to manage cotton to promote fruit retention.

Abscission Process

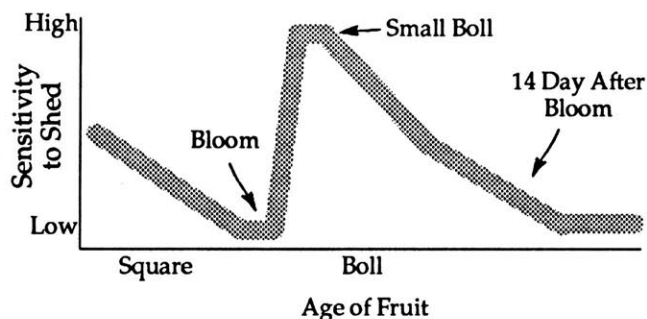
Cotton fruits shed because an abscission zone forms between the fruiting branch and the boll stem or peduncle (see drawing below). In the abscission zone, enzymes loosen the connection between cells allowing the weight of the square or boll to break the peduncle. Due to their light weight, pinhead squares with complete abscission zones often stay attached to the fruiting branch. The weakening of this abscission zone is controlled by the balance of plant hormones, ethylene (the active form of PREP), abscisic acid (ABA) which promotes abscission, and indole acetic acid (IAA) which inhibits abscission zone formation and promotes shoot growth. When the balance of these hormones swings toward ethylene and ABA and away from IAA, the square or boll starts the same abscission process that leaves undergo when a defoliant is applied. And just like defoliation, several days elapse between the stimulus (defoliant application, insect injury, or environmental stress) and the separation. During these ensuing days, when cells in the separation zone are softening, visual clues such as flared and yellow bracts tell the observant producer that this fruit will not make it to harvest.



Size of Fruit that Abscises

Insects can cause all ages of squares or small bolls to shed, but environmental problems result in the shed of only specific size fruit. By knowing the size of fruit that abscise we can often determine the cause. It's a good bet when large squares shed, insects were involved. On the other hand, heavy shed of small bolls is often due to environmental/plant causes. If we slice open the abscising square or boll, we can often tell what type of insect did the damage.

The following graph demonstrates the stages of squares and bolls that are sensitive to environmental shed. Large squares, blooms and medium size bolls are very resistant to environmental shed, possibly due to their high concentration of IAA, the retention promoting hormone. Large bolls rarely shed, possibly due to the tough vascular connections that feed the growing boll. Therefore, under typical environmental stress, the plant will shed only small bolls and small to medium size squares. If environmental stress reaches extreme conditions, for example desiccation to the point of 50% leaf loss, then an increasing number of medium size bolls will also shed.



Photosynthate Supply

Cotton plants produce sugars in the leaves that are transported to the bolls for lint and seed growth. These sugars are frequently called photosynthates (synthesized using light energy "photons"), or carbohydrates (a collective term for simple sugars such as beet sugar, and complex sugars such as starch). If the production of photosynthates cannot supply the demand then the plant stops retaining young bolls. The supply of photosynthates is decreased with low light, older leaves, water and nutrient stress and extreme temperatures. The demand for photosynthates is increased by the presence of immature bolls, rank plant growth and high day and night temperatures.

Also In This Issue
About the Authors

Jack Mauney and co-workers in Arizona have demonstrated the dramatic effect of photosynthate supply and demand on fruit set in experiments with elevated CO₂ levels. The supply of photosynthates is increased when carbon dioxide (CO₂) levels are elevated with a resulting elevation in boll set and yield, if light, water, nutrients and temperature are not limiting.

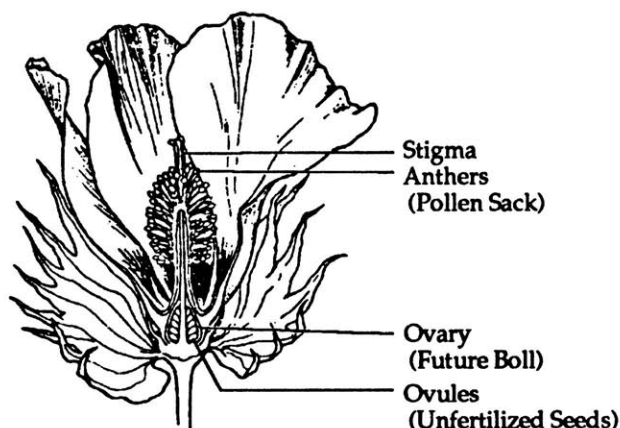
Fruit abscission, when the production of photosynthates cannot supply the demand of the fruit load, is actually beneficial because it allows maturation of big bolls which the plant has already invested time and energy. This same principle is true for many other environmental causes of abscission. The plant calculates how many bolls it can mature under the prevailing conditions and sheds the rest. Problems arise because the plant doesn't know that the heat wave will break or the irrigation water has been ordered or that the sun will come out tomorrow.

No matter how well the producer manages his crop, the boll load may build to the point that the plant can no longer generate enough photosynthates to meet the demand. Producers recognize this as cutout, when the plant ceases setting bolls and building new stems, leaves and squares. Besides cutout, photosynthate supply regulates fruit set during cloudy weather and periods of high temperature.

Light

Sunlight is required by cotton plants to produce photosynthates. During cloudy weather or at night, plants must survive on reserves that would otherwise be utilized for boll growth. Even moderately overcast days are detrimental because what our eyes see as adequate light is not enough for plants. Cotton needs full sunlight for maximum photosynthesis. In fact, cloudy summer days can be especially detrimental because temperatures are often warm, causing the plant to consume more stored photosynthates than during cooler weather. During cloudy weather young bolls are the main fruit size to be shed.

The amount of sunlight that shines into the plant canopy can also have an effect on fruit shed. Most growers have observed the self perpetuating shed of rank cotton. Once cotton gets too tall, burying the blooms in deep shade, the plant sheds young bolls.



Under these conditions, cotton will continue to grow and shed, until we slow down stem elongation with plant growth regulators or moderate water stress. This problem can be avoided by selecting a suitable plant density.

Temperatures

Growers most commonly associate hot temperatures with fruit shed but cold temperatures will also cause square shed and delay fruiting. Jack Gibson in Texas demonstrated that extremely high or low night temperatures prior to first true leaf appearance will raise the node of the first fruiting branch. Cold temperatures also may increase square shed by slowing photosynthesis and plant growth, and allowing thrips to feed on the squares. Work by Oosterhuis and Wullschleger in Arkansas suggests that night temperatures below 55°F reduces photosynthesis by 30% or more for several days despite subsequent increase in night temperatures. Cotton is one of the more tolerant plants to high temperature due to its ability to evaporatively cool even during the heat of the day. But if temperatures or temperature plus humidity reach such extremes that the plant can no longer cool itself below 90°F, then it will shed small bolls. This shed of small bolls due to high temperatures is regulated by photosynthate supply and demand. Therefore, as the boll load builds on the plant, boll shed due to high temperature increases.

Another cause of small boll shed due to high night temperatures is pollen sterility and occurs 17 to 19 days following night temperatures greater than 85°F. High night temperatures cause pollen sterility by disrupting a sensitive stage in early square development. Once these small squares become blooms we recognize pollen sterility by the failure of pollen to shed. The anthers or pollen sacks remain smooth and fail to fertilize the bloom, which then sheds as a small boll (see diagram of flower parts below).

Pollen sterility occurs infrequently outside of Arizona but shed due to high temperature is common whenever a heavy boll load coincides with high day or night temperatures.

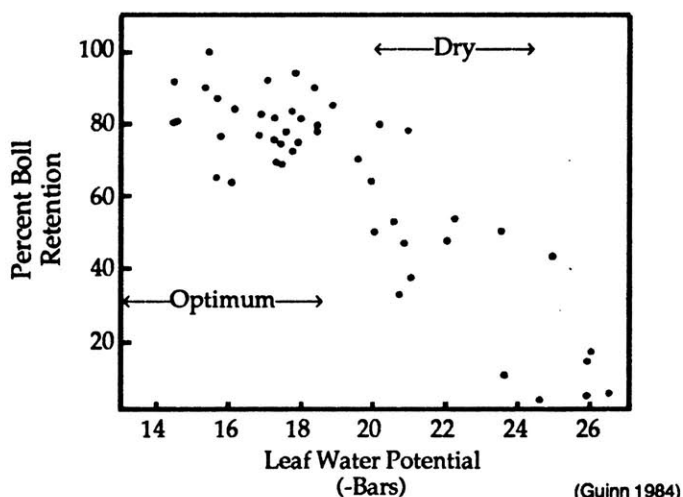
Soil Moisture

The relationship between soil moisture and fruit shed has been obscured by the interaction of moisture with insects, plant growth, soil oxygen and the time delay between a stress and the resulting shed. This relationship is further complicated because either too much or too little moisture can cause fruit shed.

We occasionally observe greater square shed in recently irrigated parts of a field versus adjacent dry strips. This square shed can be due to the increased attractiveness of wet cotton to plant bugs (lygus), a highly mobile insect. Tom Leigh in California has shown that lush, rank cotton due to high soil N and moisture attracts plant bugs. This attractiveness does not justify desiccation and nitrogen starvation, but rather avoiding excess especially where plant bugs are thick.

Soil saturation from excess moisture is another cause of abscission. In fine textured soils, the oxygen level decreases when over-watered, especially if the temperature is warm and organic matter content is high. Cotton plants close their stomates (gas exchange sites) when soil oxygen is low. The closing of stomates reduces photosynthesis, evaporative cooling, both of which increase fruit shed. Lack of oxygen has been demonstrated in tomatoes to cause production of ethylene precursors in the roots. A similar mechanism is thought to occur in cotton where these precursors move up the stem and convert to ethylene, thus inducing fruit shed.

Moisture deficiency will cause small bolls and small to medium size squares to shed. Medium size bolls may also shed if the moisture deficiency reaches sufficient severity. The figure below shows that as water stress increases beyond the optimum level, boll retention declines. When the stress is relieved by rain or irrigation, retention of blooms recovers immediately, but because squares were also shed during the stress, up to 3 weeks will be required for rate of flowering to recover. Growers often observe heavy shed shortly after an irrigation that relieves a severe moisture deficiency. This shed usually is initiated by the severe stress prior to the irrigation. But we observe the shed following the irrigation due to the time lag between stress and abscission and the increased metabolic activity in the abscission zone upon rewatering.



Desiccation also prematurely ages the leaves causing a reduction in photosynthate supply and early cutout. Even in the absence of stress, leaf photosynthetic ability will start to decline after 18 to 23 days, and when a leaf is 46 days old it can only produce photosynthate at half its maximum capacity, according to Oosterhuis and Wullschlegel. This normal decline in leaf function necessitates sufficient soil moisture for the production of new healthy leaves to support late set bolls. Oosterhuis and Wullschlegel have demonstrated the surprising fact that bracts are much less sensitive to water or low light stress and continue to feed developing squares despite a stress that damages leaves. The net effect of severe moisture

deficiency on cotton bolls is decreased boll set during the stress, a long delay before boll set fully recovers and premature cutout.

Moisture in Bloom

Rain or sprinkler irrigation on open blooms dramatically reduces set of those blooms. The water causes pollen grains to rupture before they can germinate and grow into the stigma (female surface in the bloom - see drawing on previous page). Research by Dean Pennington in Mississippi has shown that unless cotton is sprinkle irrigated during the day on a very frequent schedule, for example every 4 days, the damage from ruptured pollen is compensated by increased set on days before and after the irrigation.

Nitrogen

Cotton growers have long recognized the role N plays in productivity and have learned to manage the level of nitrogen fertilization to provide adequate N for boll filling while depleting plant N prior to defoliation.

The effect of N deficiency on fruit set is two-fold. Nitrogen deficient cotton plants stop developing new nodes and squares, and enter premature cutout. Furthermore, N deficiency slightly increases shed of young bolls. To avoid premature cutout due to N deficiency California and Arizona extension services recommend keeping petiole nitrate-N levels above 2000 ppm during the fruit set period, and Arkansas researchers recommend the use of foliar urea to provide N to deficient plants late in the fruiting period.

Excess nitrogen is also associated with shed, but is currently thought to be detrimental to fruit set only when conditions favor rank growth. In this case, the poor fruit set is caused by shading and increased insect attractiveness, not the excess N.

Disease

Most growers do not recognize disease as a major cause of shed. But disease can dramatically increase fruit shed in two specific ways. Insect feeding can introduce bacteria and fungi that cause rots and disease, resulting in shed. Additionally, vascular wilts such as *Fusarium* and *Verticillium* cause shed by preventing the plant from moving water and nutrients to the fruit. Some strains of *Verticillium* induce the production of the defoliating hormones ethylene and ABA. Cotton infested with these strains is recognized by the heavy shed of leaves and fruit throughout the plant.

Management Tools to Reduce Abscission

Fields that set a high percentage of the first position bolls can produce extraordinary yields even in short growing seasons. Besides avoiding heavy insect and disease pressure these fields must avoid the environmental conditions that promote shed. Sustained boll retention requires sustained production of new healthy leaves and squares. These fields should have adequate fertility to avoid deficiency of all macro- and micro-

nutrients. They should have the irrigation capacity to maintain sufficient soil moisture even during the hottest days.

Plant density should be low enough to allow sunlight into the upper plant canopy and illuminate the first position blooms. Proper timing and rate of plant growth regulators have been shown to increase early boll set. If producers could order weather for maximum boll set, we'd see sunny dry days, rain only at night and temperatures would cool off as the boll load accumulated. But the last couple years have taught producers throughout the Cotton Belt that they have the know-how to set a respectable crop despite unfavorable weather.

About the Authors

Gene Guinn is a research plant physiologist working at the USDA Western Cotton Research Lab in Phoenix, Arizona. Gene has worked on abscission since 1970 and authored the USDA bulletin "Causes of Square and Boll Shedding in Cotton" from which much of this newsletter was adapted.

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