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Cotton Fruit Development - The Square
Mac Stewart, Kater Hake, Derrick Oosterhuis, Tom Kerby, Jack Mauney, and Judy Timp

Cotton fields go from a pile of leaves and stems to a sea of bolls in what seems like overnight. The last 2 years in particular have been excellent examples of just how rapidly a crop can be set and matured. Part of this rapid crop development has come from the enhanced management producers have employed in the last few years. Stress in particular has been minimized wherever possible. Gone, to a large extent, are those dull gray, irrigated cotton fields where the water was started too late, those dense cotton jungles that chug a pint of Pix without even burping, those plant bug havens that celebrate the 4th of July without pinhead squares, and those “perfect sites” for next year’s test plot on potassium or disease resistance. In their place are more compact, efficient plants where sunlight reaches down to healthy leaves that feed the early bolls.

Other parts of this rapid crop development are the many unseen steps in boll development. As soon as the first true leaf appears, the cotton plant is starting to form squares. Even though the plant appears to “make cotton” overnight, it really has been forming fruit for an extended period that starts shortly after emergence.

Prebloom
Meristems and Square Anatomy
Cotton plants grow in an orderly manner, producing new parts such as nodes or squares from growing tips (meristems). Within each growing tip, cells divide into daughter cells that either continue to replicate or start the slow change into recognizable plant parts.

The fruiting branch meristems (a 40x magnification pictured at right), responsible for the development of fruit, are located in the axils of mainstem leaves, above node 5 or 6. Once a plant starts to produce fruiting branches, it is very rare that it will revert to producing vegetative branches. Below node 5 to 6, the meristem in the leaf axil is vegetative and can produce a vegetative branch or a new mainstem. Vegetative meristems are under the control of apical dominance that flows from the young tissue in the terminal. The parts of the flower are produced in a set order — first the subtending leaf, then the bracts, sepals, petals, anthers and finally the carpels (immature locks). The last formation of a fruiting branch meristem is the carpels; further growth of the fruiting branch requires another meristem to grow, which is located at the base of the square (just outside the bracts). The cells divide in the center of the meristem and turn (differentiate) into specific plant parts near the meristems edge, the oldest parts are outside of the younger parts in the flower.
Genetic Recombination

The recombinating of parental genes to make a novel genetic offspring allowed evolution to proceed at an explosive pace and species to adapt to changing conditions. Genetic recombination starts with the production of pollen cells in the anthers, approximately 22 days prior to bloom. A pollen cell has half the genetic material of the mother plant, but when combined via fertilization with an ovule (which also has half the genes) the result is a normal seed with a full set of genetic material. Shortly after pollen formation, approximately 17 to 19 days before bloom, pollen is vulnerable to high nighttime temperatures. Pollen sterility is primarily a problem of the Southern Deserts when night temperatures remain above 80°F, which results in anthers that fail to shed pollen and retain a smooth appearance the day of bloom.

Another event that occurs approximately 22 days prior to bloom is the formation of ovules. When plants experience stress (cold or hot temperatures), the number of ovules per lock in pinhead squares is reduced. Although by 22 days prior to bloom the upper limit of seeds per boll has already been set (locks per boll x ovules per lock), up to half of the ovules fail to develop into a seed and terminate development as a mote.

Square Growth

When the square is 5 days away from bloom, it starts an explosive growth in size, as the petals expand readying themselves for bloom. Large squares are now firmly attached to the plant and drawing some nutrients from nearby leaves. Young squares, on the other hand, are almost entirely fed by their own bracts, which are better adapted than leaves to either low light, cool weather or N deficiency. Large squares are also less likely to shed. Work in Arkansas indicates that insects must injure more than 30% of the square for shedding to occur. Physiological shed of large squares is rare.

Pollination

Early in the morning, when a flower opens, pollen is shed as the pollen sacks rupture. Some pollen lands on the stigma where each grain starts to grow a thin microscopic tube down toward the ovules. Cotton pollen is sticky, and thus insects, not wind, are the primary mode for pollen transfer from one plant to another. In areas where insects are controlled by frequent sprays, cotton is 95-99% self-pollinated, meaning flowers are primarily fertilized by pollen from the same plant. However, where bumble bee and other...
Cotton's high wild bee populations are high, individual plants may have as much as 50 to 60% outcrossing. Cotton's high self-pollinated percent allows seedsman to maintain genetic purity of varieties, despite only limited isolation. Experience with colored cottons in California indicates that contamination in the gin or warehouse is much more likely than by pollen from colored fields. As non-pesticide methods of insect control are developed (for example genetically engineered resistance), out-crossing may become more commonplace.

Cotton pollen is extremely sensitive to moisture and ruptures within 5 seconds upon contact with liquid water, such as occurs with rain or irrigation. As a result, rain or irrigation during the morning hours can completely eliminate boll set for that day. Some varieties do not flower or produce viable pollen under high temperatures (98°F). This has been observed mostly in those varieties adapted to cooler climates like the High Plains.

Fiber Initiation

Fibers start to elongate from the surface of the ovule on the day of bloom and can continue to elongate for a few days even if the ovule is not fertilized. These unfertilized ovules end up as motes. Because of their small size and short fibers, modern ginning equipment removes motes at the lint cleaning stage. On average, 25 to 30 lbs of motes are produced per bale of cotton, which sells for 8 to 15 cents per pound and ends up in batting, mattresses and paper. Since the fibers develop from the surface of ovules, they are strictly maternal. For example, pollen that may be transported in from a nearby colored cotton field will not contaminate that season’s lint because the lint is determined strictly by the maternal plant, but if the field is grown for planting seed, in the following year an off-type plant with colored cotton could result.

Fiber initiation appears to be very temperature sensitive, too hot or too cold, and short fibers result. Severe cold temperatures, 50°F, delay fiber initiation for 1 to 2 days, but even moderately cool temperatures, 60°F, during fiber initiation result in shorter fiber. Hot temperatures during initiation also result in shorter fiber, along with fewer seeds per boll, smaller seeds and bolls. During fiber initiation, the cells on the surface of the ovule balloon. This ballooning stage is critical in the determination of both fiber length and diameter (fineness). Based on indirect estimates, the number of fibers per seed varies widely from field to field. Approximately 20% of the cells on the ovule surface, at bloom, form fibers. The other cells continue to divide and about a week after bloom some produce fuzz fibers. The number of fibers per seed can be estimated by dividing the lint per seed in micrograms by the micronaire and staple length in inches. Fibers per seed vary between 13,000 to 21,000 depending on location. Little is known about the causes of low or high fiber counts per seed.

Fertilization

As the pollen tube begins to grow down into the flower, the pollen nucleus divides. Upon reaching the egg sack in the ovule, one pollen nucleus combines with the egg cell to start a new embryo. The second nucleus enters another cell that then develops into a nutrional tissue called endosperm that supports the new embryo. Fertilization is like a complex square-dance of cells moving about, dividing and changing; if any part gets out of step, the likely result is a mote and not a viable seed. With fertilization, the genetic cycle is now completed as the fertilized embryo contains a full complement of genetic material.

Young seeds produce hormones that increase the flow of nutrients and carbohydrates to them, thus if a boll fails to set more than 10 to 15 seeds, it cannot pull in sufficient nutrients and ultimately sheds. For this reason, unless insects damage the seeds, mature bolls with less than 10 to 15 seeds are rare. High temperature is a major cause of low seed counts. Drought and moisture in open blooms are other less significant causes. The following diagram depicts a cotton flower with its young boll on the day of bloom.
About the Authors

James McD. Stewart is a Plant Physiologist at the University of Arkansas, currently focusing on genetic tools for cotton breeders. He co-edited and wrote major parts of the Cotton Foundation book “Cotton Physiology”. This book has recently been reprinted and is now available along with the latest in the series “Weeds of Cotton”.

Tom Kerby serves California cotton growers as Extension Cotton Specialist. In addition, many of his ideas and results have been adopted by producers Belt-wide.

Jack Mauney is the other co-editor of the “Cotton Physiology” book and author of numerous scientific and popular articles on cotton physiology.

Derrick Oosterhuis is a Cotton Physiologist at the University of Arkansas. He and his research team have pioneered many areas of cotton physiology and production, such as PGR’s, Foliar Potassium and Leaf Function.

Judy Timpa is a Research Chemist with the USDA at the Southern Regional Research Center in New Orleans. Judy’s research focuses on understanding the chemical and physiological nature of cotton quality.

Narrow-Row Handbook Now Available.

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New Editor for Cotton Physiology Today

Starting with the next issue of Cotton Physiology Today, Dave Guthrie will take over responsibility for this newsletter and other activities of the Cotton Physiology Education Program. Dave comes to the NCC from North Carolina where he served producers as Extension Cotton Specialist. Dave received his PhD in cotton physiology from the University of Arkansas in 1983. Dave combines a strong cotton physiology background with a broad knowledge of production practices, having worked with cotton in California, Arkansas and North Carolina.

I have accepted a position with Texas A&M University as Extension Cotton Specialist for the Texas High Plains. Over the last 3 years, my work at NCC with the many producers, research, extension and industry personnel has provided me the opportunity to learn from cotton people all across the Belt. I thank you for all of your input and time that has made this program such a success and look forward to working with you in the future. (Kater Hake)

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