

Chapter 14:

Terminology and Concepts Related to the COTMAN Crop Monitoring System

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COTMAN™ is a computerized decision aid that integrates information on plant growth patterns, current and historical weather data, and farm and field parameters to enhance cotton crop management. Basically, COTMAN is a crop monitoring system that utilizes selected plant indicators to follow plant development and fruit load from initiation of squaring through effective flowering. COTMAN consists of two expert systems, SQUAREMAN (primarily used to monitor pre-flowering plant development) and BOLLMAN (used to monitor post-flowering plant development). This glossary of terminology and concepts associated with the COTMAN crop monitoring system is provided to explain some of the key terms used, to clarify misunderstandings, and to make the overall concept easier to understand and implement.

Terminology and Concepts

Abortion: *See* shed/shedding, damaged terminals.

Abscission: Loss of a plant structure from an abscission zone. *See* Fruit shedding, Shed/shedding.

Abscission zone: Area at the base of a leaf petiole or peduncle of a square or boll where the structure may separate from the mother plant. The abscission zone, site, or layer consists of a transverse layer of specialized cells in which the cell walls loosen and the cells expand to initiate the abscission process.

Acceptable weather risk: A choice in the BOLLMAN component of COTMAN that determines the level of risk that the user is willing to accept relative to the late-season weather. Risk is expressed as a percentage of years (based on historical weather) in which heat unit accumulation is not sufficient to mature the last effective boll population. Percentage

options include 15 and 50% of years. Changing the acceptable weather risk will shift the latest possible cutout date. By accepting more weather risk (e.g., 50%), the latest possible cutout date can be shifted to a later date. However, this increases the risk that the last effective boll population will not receive sufficient heat units to mature before harvest.

Anthesis: Developmental stage of a flower when pollination occurs which leads to fertilization, generally associated with white flower.

Average internode length: Height (length) of the main stem divided by the number of main-stem nodes. *See* height-to-node ratio, internode, vigor index.

Axil: The upper angle between the petiole of a leaf and the stem from which it grows.

Boll count: Average number of bolls per sampled unit. Boll counts times boll weight provides an indication of yield potential and may be used to indicate when a desired economic boll load has been set. Bolls set on fruiting positions nearest the main stem tend to contribute most to yield, and be of a higher quality when they are retained.

Boll/fruit load: Cotton plant's capacity to retain and develop fruit within limits of its genetic constitution and the prevailing environmental conditions. As boll loading progresses, available resources are partitioned in favor of boll development and diverted from vegetative development. The genetic constitution governs the vegetative/boll relationship, and the environment governs the available resources. The term is also used to indicate when a desired economic level of bolls has been set or when additional boll set is limited by the prevailing environmental and physiological conditions of the crop. *See* Boll count.

Boll maturity: *See* Maturity.

Boll opener: A chemical, such as ethephon or Prep®, that increases the rate of boll opening at crop maturity. Boll openers are commonly used to promote efficient mechanical harvesting.

Boll retention: *See* Fruit retention.

Boll shedding: *See* Fruit shedding.

BOLLMAN: The component of the COTMAN system that focuses on management of the boll development period. BOLLMAN is an expert system that identifies the relative maturity of fields and recommends when insect control can be terminated and harvest preparation initiated. Decision rules employ the flowering date of the last effective boll population. Fields within a farm can be scheduled for harvest using BOLLMAN by comparing their respective maturity. Inputs for BOLLMAN include NAWF counts, long-term weather patterns, local heat unit accumulations, farm-specific data on harvest capacity, cotton acreage, and the user's selection of acceptable weather risk.

Canopy: The covering formed by the leaves of the plant population in a crop. Full canopy refers to the stage when the leaves of the plants in adjacent rows meet in the inter-row and shade the soil surface.

Compensation: The cotton plant's response to fruit loss in terms of new growth, additional development, or adjusted fruit retention. The nature of the compensatory response is related to the age and growth stage of the plant, and the actual mechanism is associated with carbon partitioning and the dynamics of resource allocation within the plant.

Cotyledonary node: Opposite nodes at the base of the plant where cotyledons (seed leaves) attach to the plant. When counting first fruiting node in SquareMap, the cotyledonary node is counted as node zero.

Cracked boll: First visual sign of boll opening, when the carpel walls separate along sutures.

Crop maturity: *See* Maturity.

Crop-oriented rules: Decision rule base in BOLLMAN, which is implemented when cotton is maturing early enough that end-of-season management will be based on physiological cutout rather than on seasonal cutout. Crop-oriented rules depend on the development of the

crop rather than on calendar dates associated with long-term weather. *See* Weather-oriented rules.

Crop termination: A general term for the cessation of active crop growth in preparation for harvest. The termination of vegetative and reproductive growth is usually achieved with the use of chemical plant growth regulators or defoliant. *See* Cutout, Defoliant.

Cutout: A general empirical term used to signify the cessation or extended lapse in terminal growth because of the development of the boll load sink and the resulting demand for available nutrient and photosynthate resources. In BOLLMAN, cutout designates the end of the effective fruiting period, which may be related to the physiology of the plant (referred to as physiological cutout) or to the end-of-season growing conditions (seasonal cutout).

- **Physiological cutout:** Crop development stage characterized by an average NAWF=5. Without end-of-season constraints, physiological cutout signals the flowering date of the last effective boll population, i.e., NAWF=5 occurs before the latest possible cutout date.
- **Seasonal cutout:** When the flowering date of the last effective boll population is determined by end-of-season weather constraints rather than crop maturity. Seasonal cutout is determined in COTMAN from long-term weather patterns and called "the latest possible cutout date."
- **Premature cutout:** Early cutout associated with excessive stress, e.g., drought or nitrogen deficiency. Premature cutout will occur earlier than physiological cutout.

Damaged (aborted) terminals: Damaged mainstem tissue in the plant apex resulting in a loss of apical dominance. Plants having terminals aborted prior to first flower are avoided when using SquareMap, but will cause no procedural change for NAWF. However, NAWF counts should not be taken on a plant having an aborted terminal above the uppermost white flower.

Data logger: An electronic device for entering plant monitoring data in the field. Data are then transferred to a computer for compilation and analysis.

DD60s: *See* Heat units.

- Defoliant:** Any of a variety of chemicals that induce leaf abscission when sprayed on the cotton plant. Defoliants are frequently used to facilitate spindle-picking of cotton. COTMAN suggests that defoliants be applied at $NAWF = 5$ plus 850 heat units. *See* Crop termination, Defoliation.
- Defoliation:** Removal of the leaves of a plant or entire crop by abscission induced by a defoliant, crop development, weather, mechanical means, or certain insects and diseases. *See* Crop termination, Defoliant.
- Degree day:** *See* Heat units.
- Earliness:** An imprecise term used to represent the rapid development or maturation of the harvestable cotton crop relative to the available growing season. *See* Growth pattern, Maturity.
- Early crop:** In COTMAN, a crop that develops within the restriction of crop-oriented rules. Also, an early crop may refer to an early-planted crop.
- Effective fruiting period:** In COTMAN, the time between first square and cutout. Flowering will continue beyond this point, but the resulting bolls are not economical to manage, i.e., may not have acceptable retention, size, or quality.
- First flower (in a field):** The time when about one-half of plants in a population have developed at least one white flower, rather than when the first flower appears in the field. First flower, thus, refers to an average flowering date, and is often referred to as “50% flower.” The first flower on an individual plant will normally occur on the first fruiting position from the main-stem axis on the lowest sympodium and can generally be expected to occur about 55 to 65 days after planting.
- First flower (in COTMAN):** The earliest time that 10 white flowers can be easily detected within a sampling site in the field. Since first flower is a signal of the change from squaring to boll development, it is important to determine when initiation has begun rather than wait until the majority of the plants are flowering (i.e., 50% first flower in a field as defined above). Interpretation of plant growth can then be made by comparing NAWF at first flower to the pinnacle of the Target Development Curve. *See* Target Development Curve.
- First fruiting branch:** Earliest (lowest) formed sympodial branch on the main stem, not necessarily the first sympodium with a retained fruit.
- First fruiting node:** Lowest main-stem node above the cotyledonary node from which a sympodial branch develops. Usually occurs at main-stem nodes 5 to 7, although this is influenced by temperature and cultural practice. Typically, the first square on the plant will appear on this sympodium at the fruiting position nearest the main stem.
- First position bolls:** Bolls on sympodial branches at the nodal position nearest to the main stem. Bolls in these positions usually account for at least 60% of the total yield and have the highest lint quality.
- First square:** The first fruiting bud to appear on a cotton plant. In COTMAN the stage of growth when approximately 33% of the plants have a visible square. The first square should appear on the fruiting position of a sympodium closest to the main stem. It is recorded as the first visible appearance of the square, although the young developing square was present in the terminal much earlier. Appearance of the first square signals the commencement of SquareMap measurements. *See* First fruiting node.
- Flowering interval:** The time in days or heat units between the appearance of white flowers either at adjacent fruiting positions along the same sympodium (horizontal flowering interval) or at the same fruiting position on the next higher sympodial branch (vertical fruiting interval).
- Fruit load:** *See* Boll/fruit load.
- Fruit retention:** Presence of a square or boll at a fruiting position. It is often used to refer to accumulative square or boll retention by a plant. Fruit retention refers to normal growth and development of a fruiting structure, and is the opposite of square/boll abscission, abortion, or shedding.
- Fruit shedding:** Physiologically induced separation of a square or boll from a plant, usually induced by some damage to squares/bolls or stress on the plant. Often referred to as abscission. Occasionally, in reference to squares or bolls, the term “abortion” is used in the same context.
- Fruiting branch:** *See* Sympodium.
- Fruiting node:** Refers to main-stem nodes producing sympodia or fruiting branches. Not to

be confused with nodal positions on a sympodial branch. *See* Fruiting position, Node.

Fruiting position: A specific nodal position on a sympodium where a reproductive structure may be produced. A fruiting position may have a square, a flower, a boll, or a scar (where fruit has aborted). The majority of the yield usually comes from the first- and second-fruiting positions (prime fruiting sites) along a sympodial branch. Boll size and lint quality decrease with each fruiting position away from the main stem.

Growing degree day: *See* Heat units.

Growth pattern: Crop growth patterns in cotton are categorized by COTMAN based on the number of squaring nodes (y-axis) and days from planting (x-axis). Insight into progress of a crop may be made by comparing realized growth pattern to the standard Target Development Curve. *See* Target Development Curve.

Growing point: A mass of meristematic tissue located at a node on a main stem, monopodia, or sympodia that may give rise to a branch, branch segment, or a square. Each growing point on a cotton plant has an associated leaf (either true leaf or prophyll leaf).

Harvest (picking) capacity: An estimate, used in the BOLLMAN component of COTMAN, of the number of acres of cotton that can be picked per day.

Harvest completion date: The target date in BOLLMAN when harvest should be completed based on local perception (i.e., individual experience of the specific farm) and experience with weather patterns. *See* Historical weather database

Harvest initiation: The time when sufficient bolls are open to begin picking fields. Harvest initiation is generally sequenced among fields based on maturity.

Harvestable boll: A mature or immature boll that will open before the end of the growing season to permit mechanical harvest. Boll opening may be prevented if boll development is arrested by some factor such as excessively cool weather. Also, a harvestable boll may become non-harvestable because of boll rot, wind and/or rain damage, insect damage, or mechanical damage. A general sense of which bolls are harvestable is important in order to limit management inputs

designed to protect non-harvestable bolls late in the cropping season. *See* Maturity, Open boll.

Heat units (HU): Also known as growing degree days or DD60s. A concept that utilizes temperature rather than calendar days in describing growth and development of a crop. The concept is based on a developmental temperature threshold (usually 60°F for cotton) above which the crop grows and below which little or no development occurs. Assuming no upper threshold, the basic formula for calculating heat units involves adding the maximum and minimum temperatures for each day, dividing by 2 and subtracting the threshold temperature. Calculation of the accumulated heat units and a knowledge of the heat unit requirement for any particular growth stage can be used to explain and predict the occurrence of events or the duration of stages in crop development, i.e., as a general physiological time scale of development during the season. The expected range of heat units for any particular growth stage may be influenced by deficiencies of nutrients or water, insect infestations, disease, or physical damage by weather or chemicals.

Heat units from NAWF=5: A method in BOLLMAN used to assist with end-of-season management decisions (timing final insecticide application, final irrigation, and defoliation) based on the development of the last effective boll population sequenced by heat unit accumulation. *See* Defoliant, Insect-safe bolls, Last effective flower/boll population.

Height-to-node ratio (HNR): Average internode length determined by dividing the total plant height in inches by the total number of main-stem nodes. Plant height is measured from the cotyledonary node to the uppermost main-stem node with an unfurled leaf. Number of main-stem nodes is determined by counting the main-stem node immediately above the cotyledonary node to the highest main-stem node with an unfurled leaf, or by the number of sympodia plus first fruiting node (less one) in SquareMap. The height-to-node ratio is used as an index of plant vigor. The developing fruit load reduces the height-to-node ratio.

Historical weather database: The long-term weather data used in decisions in COTMAN.

Daily temperatures from at least 30 years at a location are analyzed to determine latest possible cutout dates to allow 850 heat unit accumulation as well as average daily heat unit accumulation that can be used to project dates that the crop will achieve target heat unit accumulation after cutout is determined. *See* Heat unit, Latest possible cutout.

Insect-safe bolls: Bolls tolerant to insect feeding.

The point in development when a boll becomes safe from insects. After a boll had accumulated 350 heat units, the endocarpal layer of the boll was rarely penetrated by boll weevil (*Anthonomus grandis* Boheman) or third-instar bollworm (*Helicoverpa zea* Boddie) larvae. Thus, the last effective boll population is projected to be resistant to these insects as soon as 350 heat units have accumulated from physiological or seasonal cutout.

Internode: The stem section between two consecutive nodes, i.e., the space between two successive true leaves on the main stem or a branch. *See* Average internode length.

Last effective flower/boll population: The latest developing population of fruit that has a high probability of being retained and developing into bolls having adequate size and fiber properties to substantially contribute to harvest. Flowering date of this population can be identified by NAWF=5 (physiological cutout) or by the latest possible cutout date (seasonal cutout). Management inputs to protect later flowers and bolls are usually wasted with little or no return on the investment.

Late crop: A subjective term that refers to bolls produced on the upper and outer periphery of the plant canopy, usually developed late in the season. These bolls may experience increased inclement weather and insect risks and are often small and have low fiber and seed quality. In COTMAN, bolls developed after physiological cutout or seasonal cutout are considered a late crop. Late crops can result from late planting or from excessive early fruit shedding.

Latest possible cutout date: Latest date from which accumulation of heat units required for boll maturation is probable, based upon the historical weather database and harvest completion date within a specific geographical region. This date

becomes later as the user assumes a higher acceptable weather risk or more southern locations.

Main stem: The central axis of the plant consisting of a terminal meristem and a series of internodes with growing points and one main-stem leaf at each node. A typical branching pattern associated with main-stem nodes would consist of inactive growing points (i.e., no branches) at the first one to four nodes (above the cotyledonary node), monopodia on the next one to three nodes and sympodia on all subsequent nodes. In cotton, the nodes, main-stem leaves and associated sympodial branches typically arise in a three-eighth phyllotaxy around the main stem, i.e., a new leaf or branch arises every three-eighths of the circumference of the main stem.

Main-stem node: The part of the stem at which a main-stem leaf is attached. In the axil of the leaf, a monopodial or sympodial branch may arise from an axillary bud. A second axillary bud also exists in the axil and occasionally generates a second branch from the main-stem node. The highest main-stem node for practical counting purposes is considered to be where the most recent main-stem leaf has unfolded. *See* Monopodium, Sympodium.

Maturity: A term used to describe the completion of natural growth and development.

- **Boll maturity:** A mature boll is one that has sufficient nutrition (carbohydrates and mineral nutrients) to open normally if the subtending leaf is removed. The boll slicing technique may be used to determine if a boll is mature. A boll that resists cross-sectional slicing by a sharp knife (due to fiber development) is considered mature. A dark seed coat is also an indication of boll maturity.
- **Crop maturity:** Crop maturity is related to a field population of plants (in relation to their environmental potential) that has developed to the point that no additional inputs are required.
- **Fiber maturity:** Fibers that have developed sufficient secondary wall thickening so that spinning and dying processes are not adversely affected. Bolls with immature fibers may open normally and be harvested.

Monopodium (plural, monopodia): A continuous, non-segmented, vegetative branch typically arising from lower nodes of the main-stem axis (as opposed to the fruiting branch or sympodium). Monopodia do not directly bear fruit but can give rise to sympodia that may bear fruit. A vegetative branch continues to produce leaves until some stress causes it to cease growth. The number of monopodia on a plant normally varies from zero to 4 depending on plant density, cultivar, planting date, and other factors. If the terminal of a main stem is damaged, particularly early, a monopodium may assume the role of the main stem. Unless a large percentage of the crop suffers terminal abortion, these plants should be avoided in plant monitoring.

Node: A point of attachment of a plant structure (leaf or fruit) to the main stem or branches of a plant. For plant mapping/monitoring, nodes on the main stem are referred to as main-stem nodes, and nodes on the sympodia are referred to as fruiting positions.

Node of first fruiting branch: *See* First fruiting node.

Nodes above first square (NAFS): In SQUAREMAN, a measure of the number of main-stem nodes above the first fruiting node or first square. *See* Squaring nodes.

Nodes above white flower (NAWF): A measure of the number of main-stem nodes above the uppermost white flower in the first fruiting position. More precisely, NAWF is a measure of the number of squaring nodes after first flower. Used in BOLLMAN as an indication of the maturity of the boll load by reference to the amount of vegetative growth (above the uppermost white flower) relative to the reproductive growth below. The upper highest node on the main stem, for practical counting purposes, is considered to be the node at which the most recent main-stem leaf has unfolded (others have used a leaf size of 1 inch). *See* Squaring nodes.

Open boll: A boll in which the carpel sutures have dehisced and allowed the seedcotton to become exposed and dry.

Physiological cutout: *See* Cutout.

Pick: The harvest of the mature seedcotton by a spindle-type picker. Originally cotton was

picked by hand, but now cotton in the United States is exclusively harvested mechanically.

Plant mapping: One of several methods used to characterize plant structure and fruiting behavior of plants by recording the location of fruiting and/or vegetative structures on the plant. Mapping techniques tend to be a single evaluation of crop status rather than a sequential series of crop characterizations, as in plant monitoring, for following crop progress.

Plant monitoring: A general term used for one or a series of interactive measurements on the plant or crop, usually made sequentially during the growing season. Management decisions are based upon thresholds and changes over sampling dates. Plant monitoring includes vigor indices, SquareMap, NAWF, petiole nutrient analysis, certain aspects of insect scouting, etc.

Plant population: An estimate of the number of plants per unit area. In COTMAN, plant population is determined by counting the number of plants in 3-foot sections of row. *See* Stand.

Premature cutout: *See* Cutout.

Prophyll: A small (about 0.2 to 0.4-inch-long by 0.1-inch-wide) petiole-less leaf formed in leaf axils, and associated with secondary axillary buds.

Regrowth: The resumption or continuation of growth that may occur after application of a harvest-aid chemical. Not to be confused with second growth.

Sample site: Location in the field where samples are to be taken. Typically, COTMAN uses 4 or more sample sites randomly selected for each field or stratum.

Sampling: Process of selecting a subset of the field population of plants to monitor for estimating the status of the entire field. Usually a fixed number of consecutive plants with relevant properties (e.g., white flowers in the first fruiting position) is sampled at each sample site.

Scar: A mark left on the stem or branch where a leaf square or boll abscised.

Seasonal cutout: *See* Cutout.

Second growth: The resumption of growth and production after cutout. Occurs primarily in regions with a long growing season. *See* Regrowth.

Shed/shedding: Separation of a leaf, square, or boll from a plant, usually induced by some stress. Occasionally, when referring to squares or bolls, the term “abortion” is used in the same context. *See* Abscission.

Simulation (crop simulation): Use of computer models, such as GOSSYM/COMAX, to mimic crop development. May be used to aid in predictions and management decisions. COTMAN does not utilize crop simulation. Instead, crop development is monitored. Various crop growth pattern scenarios relative to available growth time can be then postulated.

SQUAREMAN: The component of COTMAN that principally covers management from first square until first flower and provides a direct reflection of plant response to incipient pest and environmental stress. SQUAREMAN quantitatively measures progression of fruiting node development, fruit retention, and plant vigor. The program monitors the number of squaring nodes, plant vigor, and fruit status (number, retention, and distribution). Using SquareMap data combined with information on row spacing and date of planting, the program generates measures of plant population: total nodes; squaring nodes; fruit retention rates; vigor indices, including plant height and height-to-node ratios; days per node and elongation rates; and a graph of nodal development compared to the Target Development Curve.

SquareMap: An in-season plant monitoring technique used to assess fruiting node development and fruit retention. The data are used in SQUAREMAN. SquareMap is primarily used from first square to first flower but may be continued until cutout. Required inputs include once-per-season measurements of stand density and first fruiting node number and sequential (once or twice per week) plant maps denoting the presence or absence of squares in the first fruiting positions and plant heights.

Squaring nodes: Collective term for NAFS (prior to first flower) and NAWF (after first flower). Squaring nodes are a measure of the number of sympodia above the first-position oldest square/youngest flower throughout the effective fruiting period and is equal to the number of sympodia arising from the main stem that are too

young to have developed first-position flowers. Monitoring of squaring nodes may begin after the first squares become visible and continue until cutout. As the first square progresses to the white flower stage, the pace of plant structural development can be charted and compared to the target development curve. *See* Target Development Curve.

Square shedding: *See* Abscission, fruit shedding.

Stand (effective stand): Stand generally refers to the number of plants per area, e.g., plants per acre. Effective stand must consider not only the number of plants, but also uniformity of plant distribution, length of skips, and plant health. *See* Plant population.

Stratum: Division of a field to enhance sampling designs. For representative sampling, each field may be divided into 4 or more strata with larger samples taken from strata with the greatest production management problems and/or plant diversity.

Sympodium (sympodia): A segmented fruiting branch in cotton upon which the flowers and resulting bolls arise. This is in contrast to monopodia, which are vegetative stems, including the main stem, that do not give rise to bolls directly. A sympodium is “zig-zag” shaped with each section terminating in a node with a true leaf and a potential fruit.

Target Development Curve (TDC): A benchmark or standard growth development curve in COTMAN, which is based on number of squaring nodes plotted by days from planting. It is used in COTMAN as a standard for comparing actual growth curves. The TDC assumes first square at 35 days after planting and displays a progression in nodes above first square at a rate of 2.7 days per node. At 60 days, which approximates the time from planting to first flower, the curve reaches an apogee at 9.25 squaring nodes. The TDC then begins its descent and reaches NAWF=5.0 at 80 days after planting, with an average descent of 0.2125 nodes per day. Inferences regarding plant growth status and management decisions can be determined by comparing monitored patterns of squaring nodes to the TDC.

Terminal: Usually refers to the growing point in the plant apex but may also include the outer growing points of monopodia and, in some

cases, sympodia. These growing points consist of meristematic tissue of multiple main-stem, monopodial, and sympodial nodes.

Terminal node: Uppermost main-stem node on which the main-stem leaf is unfurled.

Unfurled leaf: The condition when a young developing leaf expands such that the unfolding edges no longer touch each other. The upper highest node on the main stem, for practical counting purposes, is considered to be the node at which the most recent main-stem leaf has unfolded. Others have used a leaf diameter of 1 inch.

Vegetative branch: *See* Monopodium.

Vegetative node: Main-stem nodes between the cotyledonary node and the first fruiting node. When a vegetative node infrequently arises above the first fruiting node, the plant should be excluded from SquareMap. *See* Fruiting node.

Vigor index: A measure of early-season growth of cotton plants, typically by evaluating plant height over time or plant height in relation to the number of main-stem nodes, e.g., height-to-node ratio. Other parameters used in assessing vigor index include elongation rate (change in height occurring between two sample dates divided by change in number of main-stem nodes) and length of the uppermost 5 main-stem nodes. These parameters are attempts to determine the rate of growth of the most recently developed nodes.

Weather-oriented rules: Decision rule base in BOLLMAN used when physiological cutout does not occur prior to the latest possible cutout date. End-of-season management must then be based on calendar dates associated with long-term weather data (seasonal cutout) rather than the physiological development of the crop (physiological cutout). *See* Crop-oriented rules.

White flower: A cotton flower with white petals that occurs on the day of anthesis (pollination). On the day prior to anthesis, the unopened flower is referred to as a candle; on the day following anthesis, the flower petals turn pink, then red.