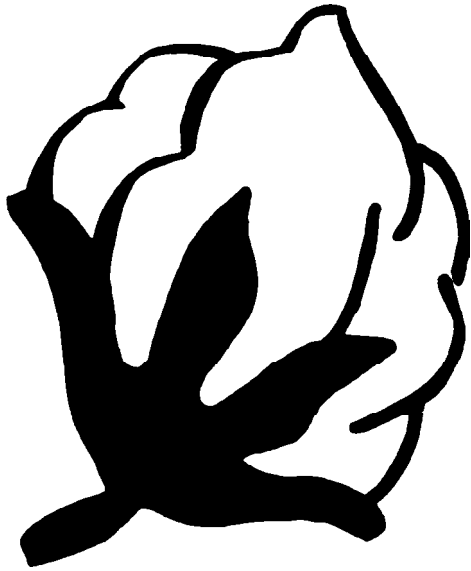




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- **Update on cotton production research**
- **Nouvelles recherches cotonnières**
- **Actualidad en la investigación de la producción algodонера**

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Introduction

Since insecticide use became popular, a need to monitor plant growth and development of fruiting parts became important for optimum realization of yields. The objective has been to keep a balance between vegetative and reproductive growths so that neither is affected by overgrowth in the other's direction. In this regard, plant mapping and crop monitoring became of significant importance. Computer-aided software further enhanced the interest of researchers and farmers to monitor plant activities and reaction to growing conditions as closely as possible. Many programs were developed in various countries and, accordingly, physiological terminology became popular. A commonly used glossary of terms related to plant mapping and crop monitoring is given in the first article.

Cotton growing conditions in Iran are favorable for high yields, and it is expected that in 1997/98 yield will be over 700 kg/ha. Iran has very strict variety zones and all varieties, with the exception of one, have been developed locally. Seed production and quality control is easier due to the limited number of varieties and only one source of seed production and supply. Insects are not a problem but verticillium wilt is a serious threat to cotton production. A hot spot of highly sick soil has been established to screen all breeding material, and only verticillium-resistant varieties are released. Research facilities are being upgraded to a mono crop multidisciplinary research institute, and programs include increasing yields and restricting cotton area to around 200,000 hectares. More details on cotton production and research in Iran are given in the second article.

India has more area planted to cotton than any other country. In 1997/98 area is expected to be over 9 million hectares. Accordingly, requirements for planting seed are also high. Complicating the seed production process in India is the large number of recommended varieties due to diversity in cotton growing conditions, and the fact that about 40% of the total area is being grown under hybrid cotton. Unlike Iran, variety approval, seed production and quality control systems are much scattered in India, but, still, farmers are provided with good quality seed. A report on variety approval and seed production in India is discussed in the third article.

In China (Mainland), cotton production is in the hands of the private sector and land holdings are small, restricted to only one-third of a hectare per family. Some unique production practices are followed that can only be practiced in such small holdings. Transplanting, topping and removal of small branches/overgrowth is common. Production practices vary, as does the pest complex. Insecticide resistance has developed to the extent that some important cotton growing areas have been taken out of cotton cultivation, especially in the Yellow River Valley. The Government of China has developed an insecticide resistance management program that includes monitoring and application of strict pesticide use principles. The resistance problem is more serious in *Helicoverpa armigera* and recommendations are different to control various generations of the bollworm. Details of the resistance management program are given in the fourth article.

The Technical Information Section of the ICAC has updated its database on current research projects. The report, *Current Research Projects in Cotton* – October 1997, has detailed information on the structure of research, institutions involved in cotton research along with complete number of researchers by discipline in each country, and names of key researchers along with their research projects in twelve disciplines. The publication is available from the ICAC Secretariat.

Meetings/Conferences

The 1998 Beltwide Cotton Conferences of the National Cotton Council of America will be held in San Diego, California, from January 5-9, 1998. The theme of the Conferences is "Managing Resources for Profitability." More information on the Conferences is available from

National Cotton Council
1818 North Parkway
P. O. Box 12285
Memphis, TN 38112, USA
Phone: 901-274-9030
Fax: 901-725-0510

The 24th International Cotton Conference Bremen will be held from March 11-14, 1998. The ITMF International Committee on Cotton Testing Methods will meet on March 10-11 and reports of its Working Groups will be presented to the main Conference. Additional information on the Conference can be obtained from the Faserinstitut Bremen.

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Preparations for the World Cotton Research Conference-2 are going on as scheduled. So far, 320 researchers from over 40 countries have pre-registered. The brochure will be revised shortly to include complete information for full registration.

All who have pre-registered will automatically receive the revised brochure. Information on the WCRC-2 is also available on the Internet at the following address:

<http://www.icac.org/icac/meetings/wcrc2/wcrc2.html>

The Sixth Meeting of the Latin American Association for Cotton Research and Development (ALIDA) will be held in Presidencia Roque Sáenz Peña in the Province of Chaco, Argentina. The Meeting will be held from December 1-5, 1997, wherein important issues related to cotton production will be discussed by a large number of researchers from various countries in the region. The Secretariat of Agriculture, Animal Husbandry and Fishing of Argentina has nominated Mr. Aldo A. Ricciardi, Cotton Coordinator of the National Institute for Agriculture and Animal Husbandry Technology, as Coordinator of the Meeting. Mr. Luis A. Pellegrino, Advisor of the Secretary of Agriculture, Animal Husbandry and Fishing, will also help in coordinating the Meeting. Dr. Mario Vaughan of Nicaragua, the current President of ALIDA, is preparing an agenda for the Meeting in collaboration with Mr. Ricciardi. A brochure on the meeting is available from the ICAC Secretariat and from the following:

Dr. Mario A. Vaughan
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Coordinador Programa Algodón
P. R. Sáenz Peña, Chaco, Argentina
Phone: 54-732-21781, 21722
Fax: 54-732-21473, 21722, 24213
Email: esaenzpe@inta.gov.ar

Information on the Meeting is also available on the Internet at the following address:

<http://www.icac.org/icac/meetings/alida6/alida6.html>

Glossary of Terms Related to Plant Mapping and Crop Monitoring

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Abstract

Plant mapping and crop monitoring using selected plant indicators to follow plant development and fruit growth has become a widely accepted technique throughout the U.S. Cotton Belt. Plant mapping refers to a technique to characterize plant structure and fruiting behavior of plants usually in single evalu-

ations, while crop monitoring is a sequential series of crop characterizations for following crop progress. New techniques to follow fruiting progress during squaring and flowering in relation to main-stem nodal development, and to assist with end-of-season management decisions have recently been introduced. However, some confusion exists about the specific terms used

in plant mapping and crop monitoring. A glossary of terminology and concepts is provided to clarify misunderstandings and to make the overall concept easier to understand and implement.

Introduction

Plant mapping is a widely used technique in the cotton (*Gossypium hirsutum* L.) industry for providing detailed information on the presence and location of individual fruit on an idealized, simplified diagram of a cotton plant. For years, use of plant mapping was limited by the inability to handle and process massive data sets. An early-developed technique for processing voluminous data was the composite plant diagram (Munro and Farbrother, 1969). This technique provided a method of summarizing data from multiple plants into a single diagram. Hake et al. (1990) presented a method of summarizing data collected from prime fruit sites for use as an in-season management tool.

The innovation of personal computers and appropriate software has greatly expanded the application and use of plant mapping. Software programs, such as the DIAGRAMMER and BOLOCATE (Smith et al., 1986; Kennedy et al., 1990), PMAP (Sumon and Landivar, 1995), CottonPro (Plant and Kerby, 1995; Plant and Bernheim, 1996) and COTMAP (Bourland and Watson, 1990), provide powerful means for summarize mapping data. The first two techniques are capable of distinguishing stage of fruit, i.e. square, flower or boll, and provide detailed information for every node. However, collection of such detailed data is tedious and statistical analyses are difficult. Coded plant data, which focus on prime fruiting sites, are used by COTMAP and CottonPro to calculate and analyze defined plant structure, fruit distribution and fruit retention variables.

Recent trends in plant-based management models recognize the importance of a more continuous in-season approach for following fruiting dynamics during the season, i.e. crop monitoring rather than an instantaneous plant map. COTMAN (Cochran et al., 1995; Bourland et al., 1992; Bourland et al., 1994) is a computerized decision aid which integrates information on plant growth patterns, current and historical weather data, and farm and field parameters to enhance cotton crop management. A glossary of terms and concepts related to the COTMAN crop monitoring system has been published (Oosterhuis et al., 1996). There have also been various non-computer programs developed for crop monitoring (e.g. Bourland et al., 1997b; Bourland et al., 1991; Hake et al., 1990).

The overall concept of plant mapping and crop monitoring is being used in many states across the US Cotton Belt. However, some confusion has arisen surrounding the interpretation of the technique and the methods by which to use it. A glossary of terminology and concepts used in plant mapping and crop monitoring is provided below to clarify misunderstandings and to make the overall concept easier to understand and implement.

Terminology and Concepts

Abscission: See *boll shedding*, *shed square* and *shed*.

Abscission zone: Area at the base of a leaf petiole or peduncle of a square or boll where the structure separates from the mother plant during abscission. 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.

Anthesis: Developmental stage of a flower associated with shedding of pollen. See *white flower*.

Boll count: Average number of bolls per sampled unit. May be used to indicate when a desired economic level of bolls has been set. Bolls set on sympodial nodes nearest the *main-stem* tend to contribute most to yield, and be of a higher quality, when they are retained.

Boll 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 (see *boll count*) have been set or when additional boll set is limited by the prevailing environmental and physiological conditions of the crop.

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

Boll retention: Normal fertilization, growth, and development of a fruiting structure; opposite of boll abscission, abortion or shedding.

Boll shedding: Often referred to as abscission. Physiologically induced separation of a boll from the mother plant, usually induced by some damage to bolls or stress on the plant. Occasionally, in reference to squares or bolls, the term abortion is used in the same context.

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.

Compensation: The cotton plant's response to fruit loss in terms of new growth, added 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, the cotyledonary node is counted as node zero.

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

Crop termination: The induction of “cutout” or the termination of vegetative and reproductive growth, usually achieved with the use of plant growth regulators.

Cutout: A general empirical term used to signify the cessation or extended lapse in terminal growth due to the development of the *boll load* sink and the resulting demand for available nutrient and photosynthate resources. 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 (referred to as seasonal cutout).

Physiological cutout: Crop development stage characterized by an NAWF=5. Without end-of-season restraints, physiological cutout signals the flowering date of the *last effective boll population*, i.e., NAWF=5 occurs before the *last possible cutout date*. See *seasonal cutout*.

Seasonal cutout: When the flowering date of the *last effective flower date* is determined by end-of-season weather restraints rather than *crop maturity*. Also referred to as the last possible cutout date. See *cutout* and *physiological cutout*.

Premature cutout: Early cutout associated with excessive stress, e.g. drought or nitrogen deficiency.

Damaged (aborted) terminals: Damaged main-stem tissue in the plant apex causes a loss of apical dominance. NAWF counts preferably should not be taken on a plant having an aborted terminal above the uppermost white flower.

Data logger: An electronic device for storing and accumulating data. Data can either be automatically entered into the datalogger via a cable from a sensing unit (e.g. temperature probe) or entered by hand (e.g. into a Psion¹ or Polycorder¹).

DD60's: 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.

Defoliation: Removal of the leaves of a plant or entire crop by chemically induced abscission or by mechanical means. Verticillium wilt and possibly other diseases can also cause defoliation. See *abscission* and *boll shedding*.

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.

Effective fruiting period: The time between first square and flowering date of the last effective boll population, i.e. *cutout* with cutout defined by NAWF=5. Flowering will continue beyond this point, but the resulting bolls are not economical to

manage, i.e., not of acceptable size or quality. See *last effective boll population*.

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 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 *sympodial branch* at the fruiting position nearest the main stem. See *first square*.

First pick: Either the process, or the product obtained, when a cotton crop is harvested by a mechanical spindle picker for the first time. Under this harvesting method a *second pick* is made at a later date to harvest late opening bolls. First pick cotton normally has fiber quality superior to second pick. The second pick is often referred to as “scrapping”.

First position bolls: Bolls on sympodial branches at nodal positions nearest the main stem.

First square: The first fruiting bud to appear on a cotton plant. The first square will appear on the first (lowest) sympodial branch at the fruiting position closest to the main-stem. Recorded as the first appearance of the square, although the young developing square was present much earlier. See *first fruiting node*.

Flowering interval: The time in days between the appearance of white flowers either at adjacent fruiting positions along the same sympodial branch (horizontal flowering interval, HFI) or at the same fruiting position on the next higher sympodial branch (vertical fruiting interval, VFI).

Fruiting branch: See *sympodial branch*.

Fruiting node: Main-stem nodes producing sympodial or fruiting branches. Not to be confused with nodal positions on a sympodial branch. See *fruiting sites* and *nodes*.

Fruiting site: A position at a node on a fruiting branch where reproductive structures, squares and bolls, are produced. See *nodes* and *fruiting node*.

Growing degree-day: See *heat units*.

Fruiting site or fruiting position: Nodal position on a *sympodium* where a boll may be produced. A scar is produced if fruit is aborted. Note that the majority of the yield comes from the first (about 60%) and second (30%) fruiting positions along a sympodial branch. Boll size and lint quality decreases with each fruiting position away from the main stem.

¹ Mention of a trade name does not constitute endorsement by the authors.

Harvest initiation: The time when sufficient bolls are open to begin first harvest in a field. Harvest initiation is generally sequenced among fields based on maturity.

Harvestable boll: A boll that will open before the end of the growing season to permit mechanical harvest. Normally, the capsule will dry and open to expose the fiber in such a way that the seedcotton is ready for mechanical spindle picking. Some immature bolls also open and can be harvested. In contrast, boll development may have been arrested by some factor such as excessively cool weather, which prevents opening of the boll and exposure of the seedcotton. 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.

Heat units: Also known as *growing degree-days* or *DD60's* (for a threshold temperature of 60°F or 15.5°C). 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. There is no upper threshold, although there is some evidence that this may be needed. 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 used to assist with end-of-season management decisions based on the development of the last effective boll population sequenced by heat unit accumulation. Research has shown that approximately 850 DD60's are required for the *last effective bolls* to mature in the Mississippi river delta.

Height-to-node ratio: The total plant height in inches divided 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. The height-to-node ratio is used as an index of plant vigor. Height-to-node ratio is very sensitive to temperature early in the year, such that before 10 main-stem nodes the ratio is generally more indicative of spring temperatures than any management decisions. Research in California has shown that prior to 7 nodes, a low height-to-node ratio will not limit yield potential because the leaves that support bolls have not yet developed. After node 7, changes in the ratio become very

important and determine stature and potential carrying capacity of the plant, e.g., 70% of the yield comes from branches on nodes 7 to 16. In Arkansas, average height-to-node ratio is 2.0 for adapted cultivars. Below this value indicates slow height development and stressed conditions, while higher values indicate excessive vegetative growth. The developing fruit load reduces the height-to-node ratio.

Insect safe bolls (bolls tolerant to insects): The point in development when a boll becomes safe from insects has been determined in caged boll tests only and is being further validated under field conditions. The endocarpal layer of the boll was rarely penetrated by boll weevil (*Anthonomus grandis* Boheman) or third-instar bollworm (*Helicoverpa zea* Boddie) larvae after a boll had accumulated 350 DD60's. Thus, the last effective boll population is projected to be resistant to insects as soon as 350 DD60's have accumulated from physiological cutout (NAWF=5).

Internode: The stem section between two nodes, that is, the space between two successive true leaves on the main stem or a branch.

Last effective flower/boll population: The latest developing population of flowers which have a high probability of being retained and developing into bolls having adequate size and fiber properties. This population can be determined physiologically (e.g. NAWF=5) or by weather restraints. See *last possible cutout date*.

Last possible flower/boll: The latest developing individual flower which will develop into a harvestable boll (last effective boll). These flower/bolls are normally associated with NAWF < 5 or anthesis after the *latest possible cutout date*, and typically exhibit low boll retention and small boll size. Management inputs to protect such flowers or salvage such bolls are usually wasted with little or no return on the investment.

Late crop: A subjective term which 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. Bolls developed after NAWF=5 or after the *latest possible cutout date* in the Mississippi River Delta are considered a late crop.

Latest possible cutout date: Latest date from which accumulation of heat units required for boll maturation is probable, based upon the historical weather patterns within a specific geographical region. This date becomes later as the user assumes a higher acceptable weather risk, or in growing regions progressively closer to the equator.

Main stem: The central axis of the plant consisting of a terminal meristem and a series of internodes with nodes and one main-stem leaf at each node. A normal branching pattern associated with main-stem nodes would consist of inactive nodes at the first 2-4 nodal positions, monopodia on the next 1-3 positions, and sympodia at all subsequent nodes. In cotton, the nodes,

main-stem leaves and associated sympodial branches arise in a 3/8 phyllotaxy around the main stem, i.e. a new leaf or branch arises every 3/8ths 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 arises 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.

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

Crop: Crop maturity is related to a field population of plants (in relation to environmental potential) that has developed to the point that no additional inputs are required. Crop maturity is indicated by *NAWF*.

Boll: 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.

Monopodial branch (monopodium): A monopodium or vegetative branch in cotton (as opposed to the fruiting branch or sympodium) is a continuous, non-segmented, vegetative branch typically arising from lower nodes of the main-stem axis. 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 four depending on plant density, cultivar, planting date, and other factors. If the terminal of a main stem is damaged, particularly early, a lateral monopodium will 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. See *sympodial branch*.

Nodes above first square (NAFS): A measure of the number of main-stem nodes above the first fruiting node or first square. See *first fruiting node and squaring node*.

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 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 (other states have used a leaf size of 1 inch). See *squaring nodes* and *white flower*.

Node: A "joint" of the stem or branch at which branches, leaves or reproductive structures develop. See *main-stem node*.

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

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

Plant mapping: One of several methods used to characterize plant structure and fruiting behavior of plants. 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. Early plant mapping methods were laborious and not practical. More recently these have been modified and incorporated into computer programs for ease of data handling, e.g. COTMAP, and incorporated into research and production systems.

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 seedling vigor indices, *NAWF*, petiole nutrient analysis, certain aspects of insect scouting, etc. See *plant mapping*.

Pick: Refers to the harvest of the mature seedcotton by a spindle-type picker. Traditionally cotton was "picked" by hand, but now cotton in the US is exclusively harvested mechanically. See *first pick*.

Regrowth: The resumption or continuation of growth that may occur after application of a harvest-aid chemical. Not to be confused with *second growth*, the resumption of growth and production after cutout in regions with a long growing season.

Sample site: Location in the field where samples are to be taken. Usually four or more sample sites will be 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) are sampled at each *sample site*.

Second growth: See *regrowth*.

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

Shed square: A square that has shed or abscised either because of a physiological stress to the plant or insect damage to the square. See *abscission*.

Simulation (crop simulation): Use of computer models, such as GOSSYM/COMAX, to mimic crop development. Used to aid in predictions and management decisions.

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

Squaring nodes: Collective term for *NAFS* (prior to first flower) and *NAWF* (after first flower). Squaring nodes measure the number of sympodia above the first position oldest square/youngest flower throughout the *effective fruiting period*, and is equal to the number of *fruiting branches* arising from the main stem that are too young to have developed first-position flowers. Monitoring of squaring nodes may begin after the first square is set on the first or lowest sympodial branch. As the first square progresses to the white flower stage, the pace of plant structural development can be charted. Under near optimum growing conditions, one can expect about 9.25 squaring nodes by the time the first square reaches the white flower stage (this assumes 25 days from first square to white flower and a vertical flowering interval of 2.7 days). Stressed plants would be expected to have less than 9.25 squaring nodes. After flowering has begun, nodal development should slow as fruit development progresses. The rate of decline will depend upon the size of the boll load of the plant and the prevailing environmental conditions. Under conditions of excellent square retention and boll set a rapid decline in terminal growth should be expected. A decline greater than 0.2 nodes per day will suggest hazardous stress, while a decline less than 0.1 nodes per day will suggest failures in providing early plant structure and/or failure to sufficiently set early fruiting positions. See *NAWF*, *NAFS*.

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

Sympodial branch (sympodium): A 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, which do not give rise to bolls directly. A sympodium is “zigzag” shaped with each section terminating in a node with a true leaf and a potential fruit.

Target development curve: A benchmark curve for measuring the efficiency of management strategies that promote earliness in the cotton crop. It begins with 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 Target Development Curve then begins its descent and should reach *NAWF* = 5.0 at 80 days after planting, with an average descent of 0.2125 nodes per day. The target development curve may be used as a benchmark to interpret actual growth curves from cotton production fields (Bourland et al., 1997a).

Terminal: Usually refers to the growing point in the plant apex, but may also include the outer growing points of monopodial, and in some cases, sympodial branches. These growing points consist of meristematic tissue of multiple main-stem, monopodial, and sympodial position 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. Other states have used a leaf diameter of 1 inch. See *node*, *main-stem node*, and *nodes above first square*.

Vegetative branch: See *monopodium*.

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 five main-stem nodes. These parameters are attempts to determine the rate of growth of the most recently developed nodes.

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

The above glossary of concepts and terminology is provided to avoid misunderstandings and to clarify the overall concept. Management efficiency in cotton can be improved by implementing strategies that may be adjusted in response to expected or realized changes in plant growth and development.

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Cotton Production and Research in Iran

Iran is not a large producer of cotton, however, cotton is important to meet its domestic needs. In the 1990s, area under cotton has averaged around 200,000 hectares. There have been years of drastic variations when, depending on the market price and competing crops, area increased to over 300,000 ha or decreased to only around 150,000 ha. It is estimated that during the current season cotton has been planted on about 215,000 hectares. On the average, current production ranges from about 100-120,000 tons. However, encouraged by high yields during 1994/95, cotton area reached 305,000 hectares in 1995/96 and Iran produced more than the required needs of the textile industry. During 1996/97, Iran exported about 30,000 tons of lint for the first time since 1979/80. Iran was an exporting country continuously for three decades in the 1950s, 60s and 70s, when during some years up to 130,000 tons of lint was exported. As in the 1980s, cotton yields have been erratic in the 1990s. Cotton area, production and yield statistics are given as follows:

Cotton Production in Iran			
Year	Area 000 ha	Production 000 Tons	Yield Kg/ha
1990/91	228	119	520
1991/92	207	118	571
1992/93	204	101	496
1993/94	148	90	612
1994/95	181	123	681
1995/96	305	165	541
1996/97	325	200	615
1997/98 (Forecast)	215	160	744

Although Iran exported about 30,000 tons of cotton in 1996, it is not ambitious to become a permanent exporting country. At the same time, it does not want to import cotton for domestic needs.

In Iran, out of the total 24 provinces, cotton is grown in 14 provinces. However, four areas produce about 90% of total production in the country.

Seed Supply and Varieties

All main varieties grown in Iran have been developed locally. Growing only one variety in a region

is recommended, and strict zoning of varieties helps to maintain varietal purity. The only major source of seed supply is the Cotton and Oil Seed Organization of Iran—an autonomous body under the Ministry of Agriculture. Usually, farmers do not keep seed, and quality of seed produced by the Cotton and Oil Seed Organization is trusted for its purity and germination. Because there is only one source of seed supply, the quantity of seed sold is always known and used to estimate planted area. The recommended seed rate is 40 kg/ha, and it is assumed that 85% of the seed is used for direct planting and 15% for re-sowing. Accordingly, the calculated planted area is used as the official estimate.

The recommended seed rate for undelinted seed is 40 kg/ha but farmers usually use 50 kg/ha. The highest seed rate used in Khorasan may reach 80 kg/ha. Until recently, all the seed supplied was fuzzy but now the Cotton and Oil Seed Organization has four acid delinting plants and delinted seed is also offered to farmers at a price 60% higher than the undelinted seed. 12-14% sulfuric acid is used for delinting and later neutralized with sodium carbonate. The delinted seed is treated with vitavax and PCNB against damping off. The recommended rate for delinted seed is 25 kg/ha. Breeders from the Cotton Research Institute work with the staff of the Cotton and Oil Seed Organization to produce a good quality pure seed. Various stages of seed multiplication are nucleus seed, breeder's seed 1, breeder's seed 2, foundation seed and certified seed.

Cotton Growing Regions in Iran

Region	Area in %	Production in %
Fars	6	25
Gorgan	40	40
Khorasan	20	20
Mazandaran	10	8

Cotton Varieties Grown in Iran

Region	Main Variety	Planting Time	Harvesting Time
Fars	Bakhtegan	March	September
Gorgan	Sahel	April-June	September
Khorasan	Varamin	May	October
Mazandaran	Bakhtegan	April	September

Cotton Research

Research on cotton is the responsibility of the Seed and Plant Improvement Center and Plant Protection and Soil Institutes of the federal Ministry of Agriculture. The Seed and Plant Improvement Center, the largest set up for research in agriculture, is based in Karg, 30 kilometers west of Teheran. Climatic conditions at Karg do not reflect true growing conditions of any cotton growing area. Thus, most of the research on cotton, particularly development of varieties, is done at the Cotton and Fiber Research Department at Varamin, a relatively hot summer area about 30 kilometers south of Teheran. The Cotton and Fiber Research Department has four main stations in the Gorgan, Fars, Ardabil and Khorasan regions in addition to many other testing sub-stations throughout the cotton growing provinces. The provincial governments also have small-scale experiments on cotton, to do research under specific growing conditions of the area. The Faculty of Agriculture of the University of Teheran in Karg trains agricultural graduates for research and extension activities in cotton and all other crops.

Recently, the Cotton and Fiber Research Department at Varamin has been upgraded to a Cotton Research Institute. In addition to agronomic and technological research, already with the Cotton and Fiber Research Department, all cotton researchers from the Plant and Improvement Center will be shifted to the Cotton Research Institute at Varamin. A blueprint has been prepared and all disciplines will be added to the Cotton Research Institute for converting it into a full-fledged monocrop multidisciplinary institute. With the objective of carrying out research under climatic and soil conditions truly representing most cotton growing areas of Iran, the government has also decided to shift the institute to Gorgan as soon as possible. It is hoped that in about two years, the incumbent plan will be completed.

Development of Varieties

Most of the cotton research work is centered on development of new varieties. In addition to introduction, hybridization and mutation breeding are used to develop new varieties. Among all the cultivated varieties, only DPL 16 has foreign origin and all others have been developed by the Cotton and Fiber Research Department of the Seed and Plant Improvement Center. Iran is actively participating in the Interregional Cooperative Cotton Research Network for the Mediterranean and Middle East Regions, which has facilitated the exchange of germplasm with other countries in the region. Active participation in the Variety Trials Working Group of the Network has helped Iran

to assess the performance of its varieties in other countries and to utilize other countries' varieties in hybridization. Breeding objectives include high yield and good fiber quality, however, early maturity and high tolerance to verticillium wilt are very important for Iran. While selecting parents for hybridizing, at least one parent must be resistant to verticillium wilt. Work is going on to utilize a radiation breeding approach. Only seed is currently radiated, at varying doses ranging from 8 to 38 krad of gamma rays. Pollen radiation at lower doses might be initiated soon. No variety from the radiated seed has been released so far. Radiation breeding has been used to enhance variability for utilization in hybridization.

Iran is also working on hybrid cotton. Through an FAO program called "Technical Cooperation among Developing Countries," Iranian researchers are obtaining training in hybrid seed production. The basic male sterile and male fertile lines are not available yet, and they might not be preferred to lines produced by hand emasculation and pollination. It is hoped that soon researchers will be able to work independently on hybrid cotton. According to breeders at the Cotton Research Institute, they have some promising hybrids showing up to 26% higher yield over commercial varieties.

Agronomic Management

Cotton is planted at a configuration of 80 x 20 cm on ridges. In hot growing conditions, as at the Cotton Research Institute in Varamin, the average number of irrigations per season is 10-12; but under humid and mild temperature growing conditions, like Gorgan's and Gonbad's, the total number of irrigations are limited to only 3-4 per season. Water supply is limited to only specific intervals and water is usually in short supply, particularly at the time of planting cotton, as the last irrigation to wheat and barley overlaps with cotton. All farmers commonly use fertilizer. Recommended doses and average soil availability is as follows:

Fertilizer Use in Iran

Nutrient	Soil Availability (ppm)	Recommended Dose Kg/Ha
Nitrogen	0.06	200-250
Phosphorous	5-6	200
Potassium	250-300	25

Research in Iran has shown that K has an effect on yield, and recommendations include its application to cotton, but most farmers do not apply it. Phosphorous

is usually applied in the form of diammonium phosphate. Fertilizer is supplied by the private sector as well as by the Cotton and Oil Seed Organization, but private sector prices are slightly higher than government prices. Weeds are a big problem in Iran and about 95% of farmers use herbicides.

The short growth period is a major factor limiting yields. Frost is often received by end of October and some bolls cannot be harvested. Competition with other crops for irrigation water does not permit planting earlier than May. Various options in the form of early planting, transplanting and plastic covering

are being tried to escape from frost damage. Simple early planting has shown stunting effects. The research data for the last few years has shown that plastic covering and transplanting are better than normal planting, but the conclusions are still far from becoming recommendations. In order to compensate for the effect of late planting, breeders are also working to develop varieties with high seedling vigor. It has been observed that varieties with high seedling vigor can better withstand the early thrip attacks and enter into the fruiting phase earlier than other varieties.

A lot of work is going on to enhance water use efficiency. Sprinkler irrigation, particularly in the Gorgan and Gonbad areas, and pot irrigation have been extensively tried. Small mud cylindrical pots placed subsurface horizontally and vertically have been found to reduce water use by 6-7 times compared with furrow irrigation. The pore spaces in the pots provide water continuously. The constituents of the mud used to make pots can be changed to increase or decrease the size of pore spaces and, accordingly, the supply of water. The pots are connected with tubes like drip tubes and always contain some water. The normal life of the system is seven years, but the economics of the system have not been determined.

Insect Control

Insects are not a serious problem in Iran yet. The average number of sprays ranges from 4-5 per season. The first spray is usually against thrips; all others are against *Helicoverpa armigera*. Whitefly does exist on cotton but still no spray is directed to control it. However, researchers have noted that whitefly population is on the increase and could become a problem. From the current population level and the extent of insecticide use, it seems that Iran is still safe from whitefly problems, perhaps for many more years. Sometimes, aphids and *Tetranychus* spp. also show up, but the population count never exceeds economic thresholds. Other occasional insects include *Earias insulana* in the Khorasan and Fars regions, and *Agrotis segetum* in the Mazandran and Gorgan-Gonbad regions. Pesticide sprays against thrips at an early stage and later sprays against cotton bollworm automatically take care of sucking insects and other types of bollworms.

Land holdings are small (national average 3 ha/farmer) and motorized back mounted sprayers are commonly used for insecticide spraying. Tractor mounted sprayers are used by some farmers in the Khorasan and Fars regions. ULV spraying is used on a very small scale. Though insects are not a major threat to cotton production, cost of plant protection operations is a crucial factor in deciding the area under cotton. Cotton prices are fixed by the government and there is no protection against minimum prices. Insecticides are supplied by the private sector in an open market, at prices determined by the pesticide industry. The Cotton and Oil Seed Organization also offers insecticides to farmers at prices usually lower than the open market. Active ingredients are imported and most insecticides are formulated locally.

Disease Control

Verticillium wilt and *Rhizoctonia solani* damping off affect cotton production in Iran. The delinted seed is treated with vitavax and PCNB against damping off. Verticillium wilt is severe in Iran and no variety can be successfully grown on a commercial scale unless it has a fair degree of resistance to the disease. Germplasm with multigenic control to verticillium wilt, caused by *Verticillium albo-atrum* and *Verticillium dahliae*, is available and extensively used in the breeding programs. The F_2 population is screened for resistance to wilt and all susceptible plants are rejected at this stage. Resistance in the selected plants is once again confirmed in the F_3 generation. A verticillium wilt hot spot has been established at Kordkouy Cotton Research Station, where agronomic practices are followed to keep the soil highly sick. A variety found resistant at Kordkouy has resistance at all other locations. In addition to F_2 and F_3 generations, after the variety has been recommended for cultivation, all single lines are also screened at Kordkouy before bulking them to produce nucleus seed for multiplication purposes. There are two races of verticillium wilt, i.e. T1 and SS4, which can be compared as follows:

Comparison of Two Races of Verticillium Wilt

T1	SS4
Attack more common over 30°C	Attack high at around 26°C
All plant leaves are affected	Only few leaves may be affected
Plant starts wilting from the top	Wilting starts from the bottom leaves
Plant dies in a few days	Plant may die slowly or recover
Potassium application lowers attack	Potassium application lowers attack
Irrigation spreads the disease	Irrigation spreads the disease
Poison is more serious	Poison may be there but it is a blockage of the xylem vessels that affects the plant
Multigenic control	Multigenic control
Has over 50 other hosts	Wide range of hosts

SS4 race is more prevalent and screening is done on the basis of morphological appearance of the plant in addition to stem cutting. The morphological grading, the main criteria used in selection, has the following grades.

Verticillium Wilt Grades Used in Iran

Grade	Description
Zero	No disease symptoms
1	Few affected leaves with yellow symptoms
2	Most leaves affected and some shedding
3	No flowers and all leaves affected
4	No flowers and no leaves

Though T1 is relatively rare, damage is more severe and results in heavy losses. Fusarium wilt is also found in Iran, but only on *G. herbaceum* varieties grown on about 5% of the total area. *G. herbaceum*, also called "Boomi," is grown in the Khorasan and Central Provinces. The Kordkouy Cotton Research Station is willing to test varieties from other countries for free.

Cotton Pricing

Seed cotton price is fixed by the government and currently serves as only an indication of the market trend. However, the actual price is usually different from the guaranteed price announced by the government. Currently, there is no system in place to keep the market price above the price announced by the government. Theoretically, the Cotton Fund, a semi-government organization established two years ago, is supposed to maintain the market price of cotton above the government price. But, due to financial limitations, the Fund has not been able to fulfil its obligations. In case prices go below the government price, the Fund should enter into the market and buy cotton to maintain the minimum support system. Recently, some new steps have been taken to make the Fund more effective and practical in maintaining control over market prices. If the Cotton Fund becomes operational and funds become available, farmers may be able to get loans from the Fund.

Future Plans

Iran is traditionally a self-sufficient cotton producing country. All the cotton produced is consumed locally in about 80 mills, most of them in Central Iran. A number of crops compete with cotton including vegetables, corn and rice. Due to high pressure for food crops, plans are to keep the area at around 200-250,000 ha but increase yields. A program called "Stability Trials" has been started to focus efforts on yield improvement. Cotton areas have been categorized into various yield potential groups and, accordingly, plans are to improve yields in each category, by more precisely meeting the needs of farmers. Lending facilities and price incentives have also been provided. About 50,000 ha were grown in the Stability Trials during 1997/98. In this program, all farmers received the highest quality delinted seed, and farm mechanization facilities were provided, in addition to technical advice suitable for various categories. The program will soon include all cotton area in Iran. The goal is to stabilize yields on the current area and then to consider expanding cotton production.

Variety Approval and Seed Production in India

In India, varieties are developed by the public and private sectors. No variety can be grown on a commercial scale unless the Government of India has officially recommended it for commercial cultivation. The promising strains developed by various breeders are tested in the All India Coordinated Trials. The trials are conducted by the All India Coordinated Cotton Improvement Project of the Indian Council of Agricultural Research. In total, 25-30 trials are conducted in three zones as follows:

All India Coordinated Trials

Region	Main States	No. of Locations
North	Haryana, Punjab, Rajasthan	6
Central	Gujarat, Madhya Pradesh, Maharashtra	10-14
South	Andhra Pradesh, Karnataka, Tamil Nadu	8-9

Some southern districts of Rajasthan are included in the Central Zone. Several small cotton growing states like Orissa, Bihar, West Bengal, Assam, Meghalaya, Mizoram and Tripura constitute the eastern region. Mostly, diploid species are grown in this region and total area does not exceed 25-30,000 ha. Zonal coordinators of the All India Coordinated Cotton Improvement Project are responsible for planting and conducting uniform trials. Interested breeders provide the varieties seed and university employees work in the development of varieties. Under the All India Coordinated Cotton Improvement Project, at least fourteen universities have research projects funded by the Indian Council of Agricultural Research and most of these projects are on development of new varieties and hybrids. Widely varying agro-climatic conditions and a variety of cropping systems

dictate cultivation of a wide range of varieties in India as compared to uniform growing conditions in many countries. There are over seventy varieties recommended for cultivation in various regions. However, varieties developed in one region are limited to testing in the same region. The main reasons are

- The date of planting cotton is different in each region. Cotton is planted in the North Region during the month of May. In the Central and South Regions, it is planted during June/July and July/August, respectively. In parts of the southern region, planting may extend from January to October. The northern region is characterized by hot climate as the peak summer temperature frequently may exceed 40°C. Temperatures are mild in the eastern and southern regions.
- In the North Region, 95% of the cotton area is irrigated and all variety development is done under irrigated conditions. Varieties developed under irrigated conditions may not be suitable for rainfed conditions of Central (except parts of Gujarat where about 30% of total area is irrigated) and South Regions. In the southern region, where hybrid cotton is grown, about 42% of the total area is irrigated.
- Soil types are also different from each other. The Central and South Regions have low fertility soils with no salinity problem, compared to alluvial fertile soils in the North with good water holding capacity and water penetration. Encrustation from light rains is common in the northern region (as happened during 1997 resulting in poor plant stand).
- Commercial cotton hybrids are grown on large areas in the Central and South Regions but not in the North Region.

- Desi cotton; *Gossypium arboreum* is planted in the North Region on a significant area.

Basic Requirements for Candidate Varieties

Not all the candidate varieties are eligible for testing in the All India Coordinated Trials. This is a measure to limit the number of varieties in the trials and, on the other hand, keep a check over the release of only good quality varieties. The varieties must meet the following base limits to be included in the All India Coordinated Variety Trials.

Basic Requirements for Candidate Varieties

Yield	Higher than the most popular variety
Staple Length	26 mm
Strength	50 gram/tex (bundle strength)
Micronaire	4.0 (in northern region, mike is slightly higher than in other regions)
Maturity	70%
UR	49%
Count Strength Product	1955
Spinning Quality	30 counts

Variety Testing Stages

All coordinated trials are coded and a different type of material is tested in different trials. The trials are named as follows:

BRO1	Germplasm testing of foreign origin.
BRO2	Initial evaluation trials of irrigated hirsutum cotton. In these trials all varieties are planted in two rows each with three replications. Only the top five varieties are carried forward for further testing.
BRO3	Preliminary variety trials of irrigated hirsutum cotton. These trials are planted with four rows of each variety and three replications.
BRO4A	Final variety trials.
BRO4B	Final variety trials for short duration compact types. These trials have six rows and four replications of each variety.

The zonal coordinator of each region of the All India Coordinated Cotton Improvement Project makes sure that all varieties included in trials get a fair chance to express their potential. BRO1 is, however, conducted directly under supervision of breeders. A committee of researchers monitors the trials in the field. The performance of coordinated trials is discussed in “zonal workshops” and suitable varieties are recommended for further testing and consideration of approval.

Variety Development Programs

More than twenty research teams at various research stations under the control of state governments are working on development of varieties. With the exception of three, all of these research stations are affiliated with the universities. Thus, most breeders in India are from the teaching staff. The Central Insti-

tute for Cotton Research at Nagpur is the only federal government institute entirely devoted to fundamental and applied production research. The National Centre for Integrated Pest Management, Agricultural Research Institute and other federal institutes do have programs on cotton in addition to other crops, fruits and vegetables. The Central Institute for Cotton Research has two regional stations, at Sirsa, Haryana, in the northern region, and Coimbatore, Tamil Nadu, in the southern region. The Regional Research Station at Coimbatore also functions as the headquarters of the All India Coordinated Cotton Improvement Project. Cotton breeders from each production region meet annually in the zonal workshop to review the progress of work and make adjustments in the programs accordingly. The program of work for next year is also considered in zonal workshops. A national meeting is held every two years. A Research Advisory Committee that includes experts from outside the institute approves the program of work of the Central Institute for Cotton Research. However, the Indian Council of Agricultural Research is the apical body for deciding research priorities and formulating national policy on cotton research. In addition, a lot of research is done by private companies, particularly to develop commercial cotton hybrids.

Seed Production

All cultivated species are grown in India in addition to inter and intraspecific hybrids. About 60% of the total planted area in India is under straight varieties, *G. hirsutum* 36%, *G. barbadense* <1%, *G. arboreum* 16% and *G. herbaceum* 8%. There are many sources of seed supply to farmers in addition to farmers keeping their own seed. The recognized stages of seed quality are as follow:

Nucleus seed	Breeders seed always in limited quantity and not for supply. It is not certified.
Breeder's seed	Seed supplied to different organizations for small-scale multiplication or utilization in hybridization programs. Requests are submitted to the Ministry of Agriculture, and seed is supplied only on the indent received from the Ministry. It is not certified.
Foundation seed	Certified seed usually supplied to farmers for planting, sometimes also referred to as Foundation 1 and Foundation 2 seed. Foundation 2 is the next generation of Foundation 1.
Certified seed	Also certified by the certifying agency and offered for sale to farmers, sometimes also referred to as registered seed.
Truthfully labeled seed	Not certified by the certifying agency but supposed to be the true variety indicated on bag. This quality seed is also offered for sale by official organizations, including the Cotton Corporation of India.

Market seed	Seed of unknown origin and sold by anyone. Purity and germination are not only unknown but also doubtful. This is the lowest quality of seed planted by farmers.
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The average total seed requirement for straight varieties at the rate of 20 kg/ha works out to be over 180,000 tons annually. It is estimated that only 30% of the total straight variety area is planted under certified seed of known origin and quality. Seed of *G. arboreum* and *G. herbaceum* varieties is not certified.

Production of Hybrid Seed

Commercial cotton hybrids are grown on about 40% of the total area in India. Certification of hybrid seed is entirely different from straight varieties. If a public sector breeder has identified the parents, the breeder's seed of both parents is received from the respective breeder. The parents are supposed to be pure. The breeder's seed is planted and in fact is the foundation stage population that is crossed for F_1 seed production. If a private company identifies the combiners, it makes sure that parents are pure, otherwise hybrid vigor may be lost. Self-accountability and competition among private seed supply companies dictates careful maintenance of parental lines.

Seed prices vary from season to season but the F_1 seed is usually sold at the rate of 300 rupees per half kg. The price of a normal variety seed is about 30 rupees/kg. Hybrid seed is expensive and a very low seed rate, i.e. about 2.0-2.5 kilogram per hectare, is recommended depending upon the plant type and seed index. If the plant is tall and bushy and seed index is low, a low seed rate is advised. However, in order to make the best use of the expensive seed, planting by dibbling is also recommended. For hybrid seed production, male and female parents are usually planted in a ratio of 1:5 in adjacent fields. Sowing dates of parental lines are adjusted so that they synchronize in flowering. If the flowering period of the male parent is too short, sowing dates are staggered in order to make use of all flowers on the female parent. Private companies must understand the morphological characteristics of both the identified combiners for removing off type, if any, before crossing work is started. The technical staff of the state seed certifying agencies can be invited to undertake periodical inspections and help remove off types. Usually the fields are visited three times, i.e. before flowering, at peak flowering and before picking, by the staff of the certifying agency and only after these inspections the field is certified as pure. Purity of the male parent is even more important as one male flower is used to pollinate 5-6 female flowers.

Physical purity, genetic purity and viability tests are conducted before the hybrid seed is certified as fit for planting. Seedcotton is ginned in designated ginning factories in the presence of a representative of the seed-certifying agency. Genetic purity of the F_0 seed is tested just after harvesting in the "grow-out test" by raising seedlings under field conditions. The main task here is to identify female parent plants in the F_1 generation. The physical purity is tested based on the look of the seed. The

minimum standards followed are germination 65%, physical purity 97% and genetic purity 90%. As per Seed Certification Standards, the F_1 seed is acceptable if out of 10% suspected off types, 8.5% are female plants and 1.5% off types do not conform to either F_1 generation nor female parent. The performance of grow-out tests will depend on the skill of the labor involved in hand emasculation and pollination. Private seed companies usually do not conduct grow-out tests, but utmost care is taken to avoid selfing, and the quality of seed produced by private seed companies is understood to be equally good. Currently, about 55% of hybrid seed requirements are met by the private sector.

Seed Certification

The Cotton Control Act prohibits cultivation of unapproved varieties. The law does not permit marketing of unapproved varieties either. State governments are entitled to permit cultivation of a specific variety in a specific area. The Seed Act and Seed Control Order has streamlined seed production in India but good varieties can be lost easily if the seed production system is not good, and no seed production system can work well unless there is a strict quality control system in place to avoid mixing and provide assurance to buyers. Thus, certification by a third party is useful for maintaining the interest of growers in quality seed. Quality in seed production refers to purity of the variety and germination. In India, many years ago, certification was done by a National Seed Certification organization but now state governments have set up their own seed certification agencies. Seed certification agencies are autonomous in function and play a very important role in the cotton seed industry in India. According to the Seed Act of India, seed certification agencies are only competent to certify crop and seed of notified varieties.

There is a fee for certification and any company or individual can apply for crop certification. Applications can only be submitted on a prescribed format giving all the details of the seed source and field plots. If a field or a seed lot is rejected, the company or individual has a right to make an appeal to a designated state government agency for reconsideration, whose decision will be final.

Role of CCI in Seed Production

In the last few years, the Cotton Corporation of India (CCI) has played an important role in seed production and supply to farmers. CCI is an autonomous market oriented organization under the Ministry of Textiles. The main task of CCI is to undertake price support operations so that the market price does not fall below the price announced by the government. CCI can also buy cotton from the open market and do business at its own risk in addition to exporting any quota allocated by the government. In the seed business, CCI's approach has not been to take over seed production, but to augment efforts of the state seed corporations for providing certified seed. The respective state seed corporations, departments of agriculture and breeders in-

volved in the projects train farmers involved in seed production. Orientation training programs have been launched in various states, aimed at producing high quality seed of most popular varieties of the area. Farmers who enroll in the programs and follow recommended seed multiplication practices are re-

warded by CCI through financial incentives. The programs took off in 1993/94 when 63 tons of certified seed were produced; the target for 1997/98 is 2,600 tons. Moreover, CCI also purchases high quality seed from state seed corporations to supply to growers on a non-profit basis.

Insecticide Resistance Management Approach in China

In China, cotton is grown in three regions: the Yellow River Valley (North Region), the Yangtze River Valley (South Region) and the Xinjiang Region. The Xinjiang Region, also called the desert area, is characterized by a short growing season. Here, cotton is grown under very high density, i.e. about 150,000 plants per hectare, which enhances maturity. On the average, five bolls/plant are considered to be enough for optimum yield. In order to escape from late maturity, all cotton is planted under plastic covering. Most of the area is irrigated and growth regulators are commonly used as a measure to check growth and enhance maturity. Among pests, verticillium wilt is a serious problem, though fusarium also exists and sometimes may cause losses. Aphids are a major threat among insects but granules are commonly used to save the crop at early stages. On the average, 1-2 sprays are enough to save the crop from any heavy losses. Average yield is about 1,200 kg lint/ha.

The Yangtze River Valley is characterized by the transplanting of cotton seedlings, though plastic covering is practiced to some extent. Most area in this region is also intercropped with wheat: cotton is planted in wheat when it is at tiller formation stage (mid April). On average, cotton and wheat overlap 30-45 days, and when wheat is harvested in June, it is too late to plant cotton. Two rows of cotton are planted after every four rows of wheat. Plant population is almost half of that in the Xinjiang Region. Rice, corn and rapeseed are competing crops. Verticillium wilt and seedling diseases are common, but boll rot is a more serious problem. Many cultural operations are followed to avoid boll rot, including three applications of pix, but elimination of aged leaves and young squares is recommended by researchers and commonly practiced by farmers. Among bollworms, *Pectinophora gossypiella*, pink bollworm is a common insect. The average number of sprays to control pink bollworm and spider mites is 5-6 and may exceed ten in some years.

In the Yellow River Valley, direct planting under plastic is the most common method of planting cotton. Transplanting and intercropping are also practiced on a small scale. Verticillium wilt and seedling disease are prevalent almost every year. This area has been hard hit by insecticide use. *Helicoverpa armigera* has developed resistance to a number of insecticides. The average number of sprays has increased significantly, particularly since the late 1980s. In order to secure good protection against bollworms, farmers may have to spray ten or more times. Pink

bollworm does exist, but most sprays are directed to control cotton bollworm. Pheromones are commonly used to attract male bollworm moths. One trap for every one-fifth of hectare is recommended, which is a normal cotton planted area per family.

Cotton Bollworm Resistance

According to Xia (1993), eight insect species are reported to have developed resistance to one or more groups of insecticides: *Helicoverpa armigera* (cotton bollworm), *Aphis gossypii* (aphid), *Tetranychus* spp. (spider mite), *Pectinophora gossypiella* (pink bollworm), *Agrotis* spp. (cutworm), *Earias* spp. (spotted bollworm), *Adelphocoris* spp. (plant bug) and *Amrasca* spp. (jassid). But, of these insects, cotton bollworm resistance is the most serious and has increased the number of sprays to uneconomical levels in the Yellow River Valley. During the 1950s, aphids, spider mites and pink bollworm were major insects. American bollworm was there but there was hardly a need for spraying against this insect. During the 1960s and 70s, the second generation caused economic losses and the third and fourth generations appeared on cotton. During the 1980s, the second, third and fourth generations caused serious losses in yield. During the early 1990s, the fifth generation also appeared at the end of the crop season and insect pressure on the plant further increased, causing heavy losses in production. Similarly, egg counts per 100 plants increased from 200-300 in the 1950s to 925, 1351 and 2000 during the 1960s, 1970s and 1980s, respectively. Now, it is hard to control the bollworm in spite of aggressive insecticide usage. Cotton bollworm generations that show up on cotton and other crops and their time of appearance are as follows:

Cotton Bollworm Generations in China

Crop	Yellow River	Yangtze River	Xinjiang
Wheat and other crops	1 st	1 st and 2 nd	1 st
Cotton	2 nd , 3 rd and 4 th	3 rd , 4 th and 5 th	2 nd and 3 rd

Time of Appearance of Generations

First generation	Mid June – Mid July
Second generation	Mid July – Mid August
Third generation	Late August – Mid September

Aphids have also developed resistance to many commonly used insecticides and are posing a similar threat. Currently, the Government of China (Mainland) has two programs to manage insecticide resistance. One deals with research, and the development of recommendations, while the other is the actual implementation of recommendations at the farmer's field level. Most efforts are directed to manage first, second and third generations. Thresholds for the three generations are as follows:

Economic Thresholds for the Cotton Bollworm

First generation	200-300 eggs/100 plants or 20-25 young larvae/100 plants
Second generation	100-150 eggs/100 plants or 10-12 young larvae/100 plants
Third generation	200-300 eggs/100 plants or 20-25 young larvae/100 plants

Cotton Bollworm Resistance Management Program

The Cotton Bollworm Resistance Management Program is run by the China Cotton Research Institute (CCRI), Anyang, Henan. The program is research oriented and has two components: monitoring and management. In order to monitor the status of resistance, CCRI has selected 22 counties, with each location having laboratory facilities to test resistance to insecticides. Most locations are in the Yellow River Valley because it has the most severe resistance problem, with 3-4 in the Yangtze River Valley and a few in the Xinjiang Region. The topical application method is used to check resistance to pyrethroids, organophosphates and carbamates. The two or three most commonly used insecticides from each group are tried on the susceptible population versus the field population. The leaf dip method, recommended by the Pesticide Action Committee, is also used. Relationship between the two methods is also being established. Although the mechanism of resistance is being investigated, it is understood that multiple function enzyme and insensitivity (nervous system) both are responsible for development of resistance.

The management aspect relates to understanding the population dynamics and role of biological agents in various counties for reducing the use of insecticides. Considerations also include use of such chemicals so that development of resistance can be delayed. Accordingly, based on the level of resistance found in various counties, CCRI makes recommendations to avoid further deterioration in the level of resistance and make use of non-chemical methods as much as possible.

Resistance to Bt insecticides is also being studied at the CCRI but it is not a part of the Cotton Bollworm Resistance Management Program.

Integrated Pest Management

The IPM program is of an applied nature and is run directly by the Ministry of Agriculture. Based on the Cotton Bollworm

Resistance Management Program of the CCRI and the experience of other experts at the cotton growing provinces, a package of recommendations has been prepared by the Ministry of Agriculture. More than twenty counties were included in the project area in the Yellow River Valley during 1996 to follow the recommendations from the government and use only prescribed chemicals. Insecticide resistance management could be different for different counties depending upon the production practices and type of planting, i.e. single planting or intercropping with wheat. The package includes the following recommendations:

- Only acid delinted seed should be used for planting in the project area.
- Planting seed should be coated with chemicals to keep the crop safe from aphids for a few early weeks. Applying granules is recommended also as it is estimated that seed coating and granule applications save two early sprays against aphids.
- For bollworm control, the recommendations are different for different generations. These are

First Generation

- In the Yellow River Valley there are usually three generations of *Helicoverpa armigera* that affect cotton; at an early stage it is recommended to use only chemicals that have an ovicide effect.
- Cotton bollworm prefers fruiting parts. But, when it shows up in the field, there may not be flowers, buds or bolls on the plant. In the absence of fruiting parts, the bollworm will attack the apical growing shoot and change the plant morphology. Using one drop of monocrotophos on the apical growth to avoid topping is recommended.
- The 2nd spray is again with chemicals having an ovicidal effect. In the third spray, pyrethroids can be used.
- Other methods used are high voltage light traps to attract bollworm moths and kill them manually.
- Among other non-chemical methods for the control of the first generation, the Ministry recommends putting a bundle of poplar tree branches close to the cotton field. Bollworm moths are attracted at night and farmers kill them in the morning.
- Planting one row of corn as a trap crop after every 10-12 rows of cotton is recommended. Farmers visit corn plants and kill bollworm larvae. Bollworm also lay eggs on corn, which is good for cotton. Corn shelters beneficial insects at the time of spraying insecticides.

Second Generation

In the second generation, it is very important to hit the insect through chemical means and kill it directly. Organophosphates, carbamates and their mixtures are recommended. The aphid population increases by this

time and chemicals that also control them are preferred. By this time the crop is already pruned and topping is recommended.

Third Generation

Artificial control is recommended for controlling the third generation. In mid-August or early September, all young new branches on the cotton plant are to be removed from the plant. The objective is to minimize the feeding material for the insect and divert all plant energy to forming bolls and maturing already formed bolls. It also improves sunlight penetration down to the lower part of the plant and helps reduce boll rot. If a chemical spray is needed, which is common in areas like Shandong, only organophosphates and carbamates are recommended. Pyrethroids are forbidden at this stage.

Other methods recommended include the following:

- Application of microbial insecticides like Bt and nuclear polyhedrosis viruses is strongly recommended.
- Sex pheromones are recommended and commonly used by almost every farmer in the Yellow River Valley.
- As a cultural measure, it is recommended to plant rapeseed in wheat and cotton fields and corn rows in cotton for trapping aphids and bollworms, respectively.
- Recommendations also include cultural operations like ploughing cotton fields during winter.

In China, wheat-cotton intercropping is detrimental to the insecticide resistance management program. If wheat is planted after cotton, not only emergence is high but also bollworms survive on young wheat grains and flare up in adjacent cotton

fields. Spraying wheat for the sake of controlling bollworm is not recommended.

According to Sheng (1997), in 1996 the pilot project of the Ministry of Agriculture was conducted in 21 counties on an area of over 20,000 ha each in the Yellow River Valley. The number of sprays was significantly reduced in the project area compared to 1995, when farmers followed routine practices. The cost of plant protection measures decreased by 20% over 1995.

The worst affected area in terms of resistance to insecticides in China is the province of Shandong. Reports show that during 1996, the bollworm population was higher in Jiangsu, close to the Yangtze River Valley. The bollworm population is also increasing elsewhere. According to Sheng (1997), growers in the Xinjiang Region experienced serious damage to cotton by the cotton bollworm in 1996. It is estimated that about 45% of the total area planted to cotton, or almost a 7-fold increase over 1980, was affected by bollworm in 1996. The area under cotton in Xinjiang has increased continuously since 1980, thus raising its share to about 25% of total production in the country. Although an exceptionally high population of the cotton bollworm in 1996 is attributed to favorable weather conditions and farmers' all out efforts to control only aphids, the bollworm population in Xinjiang is on the increase too, which is alarming.

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