HORMONAL MANIPULATION TO INCREASE COTTON PRODUCTIVITY

Prakash, A.H., N. Gopalakrishnan & S.E.S.A. Khader

Central Institute for Cotton Research, Regional Station, Coimbatore

Introduction

Cotton, basically a perennial plant is domesticated and now grown as a forced annual. Through intensive breeding programmes many of the perennial characters are masked and the present cultivars are photo insensitive with determinate growth habit. But under unfavourable conditions, it reverts back to its perennial nature.

The cotton plant has perhaps the most complex structure of any major field crops. Its indeterminate growth and sympodial branch often defies analysis. Physiological efficiency of the plant holds the key for ideal performance of the crop in terms of growth, development and yield. However, efficiency is governed by many biotic and biotic influences. Once an ideal genotype for a particular region is identified in terms of duration, productivity, growth habit and compatibility in the overall cropping system the endeavor should be to optimize the yield realization through appropriate management methodologies including nutrient, moisture, insect pests, diseases and physiological maladies affecting the crop.

The indeterminate growth habit of cotton crop gives it leverage to overcome considerable early damage and still make adequate yields due to mid and late-season growth. Certain kinds of mechanical damage to young cotton such as early hail damage to cotyledons, thrips feeding, and water stress prior to flowering have shown to cause little or no reduction in yield. Though 7-10 days of earliness may be lost by this damage, the delay have negligible effects on harvest in most season.

With the great effort of green revolution, there was a tremendous improvement in cotton production and productivity. The improvement was due to the combined effect of genetic improvement, increase in area under cotton crop and fertilizer inputs. Now the plateau has been reached in terms of genetic improvement due to non-availability of better genetic diverse genes for improvement. The suitable cultivable land is becoming a limitation for further increasing the cotton area. There is a steady increase in the demand for nature fibre to meet the requirements of increasing population and also for export needs. Due to the population explosion and also the saturation in cotton area, new efforts should be initiated to enhance the productivity. This is possible only through the second green revolution through the physiological manipulation of crop growth and development, thereby enhancing the productivity per unit area. Till date the enhanced production was only by improvement in genetic resources and high inputs. Not many efforts were put to understand the physiological factors for enhancing better yield through judicious use of land and plant architecture.

About 70 per cent cotton cultivation in India is under rainfed conditions. Cotton suffers from various biotic and abiotic stresses right from the germination to maturity. The growth during the seedling establishment phase has a role to play in yield realization. A good plant frame would provide sufficient space for holding and catering the needs of the reproductive parts during the later part of growth. In northern parts of India the seedlings are exposed to high temperature during the seedling development stage, while in central and south India, the crop experiences waterlogging initially and followed by sucking pests. Both these stresses cause considerable damage to the plant leading to stunted growth. As the cotton plant is photo-insensitive, they starts producing the reproductive parts irrespective of the environmental and physical conditions by 40-45 DAS. Hence sufficient morpho-frame will not be available for the plant to hold the reproductive parts. This leads the plants to either premature death or reduced boll load.

Modifying cotton growth has become an essential component of cotton production, whether by making adjustments in fertility, water management or use of harvest aids. Applying plant growth regulators to modify early and midseason growth is similar to other management practices. There is potential to influence yield if they are managed properly.

Plant growth regulators:

The key to modifying growth is knowing what the plant needs at each stage of development to reach the final goal of higher yield and quality. The next step is to do everything possible to provide for these needs. Plant growth regulators have the potential to promote crop earliness, square and boll retention, higher nutrient uptake, and keeping vegetative and reproductive growth in harmony to improve lint yield and quality.

Several naturally occurring hormones work in the cotton plant to adjust plant growth. When plant growth regulators are applied to the cotton plant, they work in much the same way as the natural regulators already present. In many ways, they supplement or destroy the natural hormone. They often will work together in ratios and concentrations to regulate growth. Some naturally occurring hormones are auxins, gibberellins and cytokinins. Some of the more common plant growth regulators are composed of these hormones or combinations of them. There are other groups of growth regulators also which play an active role in plant growth and development, as listed in Table 1.

Morphological development of cotton plant: Initiates with the vegetative growth. The primary axis of the plant remains vegetative through out. Axillary branches differentiate at the base of each leaf on the plant, these branches are responsible for all vegetative limbs (monopodia), and reproductive branches (sympodia). There are usually two axillary buds at the base of each leaf with the second bud dormant. At lower nodes, the axillary buds are vegetative and elongate into vigorous vegetative limb. On the sympodial branches, these buds will modify into floral branches.

Table 1. Plant growth regulator class, associated function(s) and practical uses.

Class	**Function(s)**	**Practical uses**
Auxins	Shoot elongation	Thin tree fruit, increase rooting and flower formation
Gibberellins	Stimulate cell division and elongation	Increase stalk length, increase flower and fruit size
Cytokinins	Stimulate cell division	Prolonging storage life of flowers and vegetables, bud initiation and root growth
Ethylene generators	Ripening	Induce uniform ripening in fruit and vegetables
Growth inhibitors	Stops growth	Promote flower production by shortening internodes
Growth retardants	Slows growth	Retard tobacco sucker growth

Since all the reproductive branches arise at the base of vegetative leaves, the initiation and the rate of formation of sympodia are partially dependent on vegetative growth. After initiation, the continuation of flowering is a function of vegetative growth, which produces sites for additional fruiting branches, and formation of additional nodes on existing branches.

The base rate for successive initiation of additional fruiting branches, vertical flowering Interval (VFI) and the rate of adding successive nodes along the fruiting branches (Horizontal Fruiting Interval (HFI)) was studied and a relationship was termed as “ISOPHASE” with a ratio of HFI/VFI of 2.5.

Flowering habit of cotton is complex and extents over a long period, considerable research has been directed at describing and quantification of fruiting sites by the plant. The first flower buds are borne on the fruiting branches at fifth to tenth main stem node. Flower buds open as blossoms about three weeks after they are first visible. After the first fruit (bolls) are set, the growth rate of the main stem slows eventually stops. For a time, blossoms open at a faster rate than new floral branches re formed. When all floral bud sites formed in the initial vegetative growth phase have matured into blossoms, there is a hiatus in flowering known as cut-out. Subsequently, the resumption of vegetative growth produces new floral sites and a second flush of flowering occurs. Though sympodia are morphologically indeterminate, they generally are limited to three active floral nodes in field conditions.

All processes leading to square, blossom and boll initiation and maturation are temperature dependent. Under favourable sunlight, temperature and agronomic practices each plant can produce about 15-20 symposia and about 50 squares which will blossom aver a period of 60 days of which 50,30 and 10% of the squares at the sympodial nodes 1, 2 & 3 respectively, mature into open bolls. From these, 10-15 bolls can be expected to mature into harvestable lint and seed.

The data quantifying flower site production and interactions with environmental factors appear relatively complete. However, none seems to answer clearly the persistent question of why there are situations in which excessive square shed or extreme vegetative growth produces tall, relatively barren plants.

The ratio of vegetative structure of each plant to the reproductive sites is a function of the number of vegetative nodes below the NFB, the vigour of vegetative limbs and the number of flower sites on each sympodia. Hearn (1969) found that plant density was a primary determinant of the number of vegetative limbs and that the no. of flower sites per sympodia was determined by the genetic and internal competition among branches.

Early work on crops with growth regulators was concerned primarily with their effects on flowering. More recently, their biochemistry and physiology have been studied. Many practical uses of GR have evolved from these basic studies. They can be used effectively on plants to: induce rooting, decrease lodging, regulate tillering or suckers, fruit ripening, retain or shed flowers and leaves (like chemical fruit thinning and leaf defoliation), fruit set, slow down plant growth, delay aging, and aid in mechanical harvesting.

Based on the need the plant growth can be regulated at various stages by using action specific growth regulators-

Delay flowering: Application of ethylene induces the young squares to shed, there by delay first bloom. Prakash *et al*. (2005) at Central Institute for Cotton Research, Regional Station, Coimbatore, demonstrated the foliar application of 2-chloro-ethyl phosphonic acid (ethrel) to induce abscission of squares in cotton. Application of 30 ppm of ethylene in the form of commercial formulation – Ethrel at 35-40 days after sowing, induced the shedding of young pin head size squares. The plant reverted back to vegetative growth for about 10 days, put forth more morphoframe before re-entering the reproductive cycle. This helps the plant to develop the required vegetative frame before entering the reproductive phase and enhance the seed cotton yield by 25-30 percent. There are other reports wherein, Maleic hydrazide is used to delay flowering in corn (Josephson, 1951)

Fruit abscission, due to any reason, can cause plant to redirect assimilate to alter sinks ands shift dry matter allocation from reproductive to vegetative organ. The reproductive sink removal increased plant height (Patterson et al., 1978), increased the root development and branching (Prakash et al., 2005). Concurrent with these increase in the vegetative growth, fruit removal increased square production (Rao et al., 1996). The yield gap between potential and actual yield is very high. Through the physiological modification of the plant growth this can be reduced (Prakash et al., 2005). Simulated square shedding near a critical time trigger photosynthates from reproductive sink to vegetative sink and ended up in robust plant type (Makhdum et al., 2002, Prakash et al.., 2004).The crop simulated to flower bud coupled with complete removal during bloom stage could not be compensated for its fruit loss compared to removal during squaring (Jones et al., 1996).Compensatory mechanism due to square removal was not observed in short duration genotypes and there was yield loss, while the medium and long duration genotypes showed not only compensation but enhanced the yield by 15-20% (Prakash et al., 2003).Crop with very high early-season fruit retention, may lack sufficient pre-bloom vegetative, which may cause early cut-out, if the crop is stressed.

Reduce the monopodia number: Applied 2,3,5-Tri-iodobenzoic acid (TIBA) @ 5g/ha five times to lower the position of the first fruiting node, increase boll size and increase the number of bolls per plant (Freytag and Coleman, 1973). They postulated that TIBA inhibited auxin transport and decreased endogenous ethylene concentration. The yield increase was to an extent of 16%.

Enhance flowering: Application of GA (100 ppm) directly to open flowers and young bolls increased the boll retention percentage (Walhood, 1958). Application of GA. increased the plant height and the boll no. but decreased the boll size. A few reports indicate increase of boll retention and yield by two sprays of NAA (30ppm) at the flower initiation and peak flowering. These chemicals are basically growth promoters.

Square and boll retention: NAA (30 ppm) is also effective in controlling of shedding. Application of silver Thiosulphate @ 5-10 µM at peak flowering will reduce the shedding and enhance yield by 20-30%.

Delay leaf senescence: Application of urea (1%) + Magnesium sulphate (0.1%) at peak flowering will delay leaf senescence. Similarly application of Thiourea @ 1% will protect the leaf from senescence and there by increase the leaf photosynthetic efficiency.

Vegetative growth retardant: The GR chemical PIX (1,1-dimethyl-piperidinium-chloride) is an effect chemical in controlling vegetative growth. PIX at rate of 25-50 g ai. /ha applied at early bloom stage reduced the plant height by 20-40cm than the control. It also reduced the length of the lateral branches, there by increased the boll retention by indirectly reducing the shading effect on developing squares and bolls.

There are large no. of growth retardant applied to curtail the vegetative growth and unproductive reproductive growth. Application of CCC (Cycocel and Chlormequat)@ 40ppm at 80-90 DAS reduced the unproductive growth and increased the yield by 16-34% and induced uniform bursting.

At Central Institute for Cotton Research, Regional Station, Coimbatore, study indicated that foliar application of Maleic hydrazide @ 500 ppm at peak boll development stage, suppressed the apical growth but enhanced the leaf area expansion by 10-15 days. Similarly application of chlorethyl-hydrazonium chloride (CMH) @ 480 & 720 g/ha reduced the growth but increased the boll retention.

Practical utility: Modern varieties of cotton flower readily without special photo-periods or hormonal modifications. Cotton crop failures can be often related to excessive vegetative growth. Lush 2 –2.5 mts cotton canopies with fully overlapping middle canopy are havens for insects, and verticillum wilt and boll rot fungi. A luxuriant and dense canopy makes effective insect control essentially impossible and causes lodging, which makes harvesting difficult. More over, squares or small bolls may shed due to shading effect. The reduced plant growth and modified shape, which result in better light penetration, earlier boll opening and higher harvest, index. Relatively little is known about hormonal control of cutout, but based on established effects of the hormones, it is speculated that auxin, cytokinens and Gibberellins promote growth and delay cutout. ABA, on the other hand promotes cutout as it inhibits growth and prolongs bud dormancy. Ethylene increases boll abscission and may restrict growth, but may not induce dormancy of buds. Various growth regulators have been applied in cotton in attempts to set more bolls, limit vegetative growth or terminate fruiting. When boll load is limited by carbohydrate supply, exogenous modification of hormonal balance to increase boll set may be futile. More bolls may be set, but will be of smaller size and plant growth is terminated prematurely. Hormonal regulation of plant height is possible, and may be a useful practice where bushy growth of plant is observed and the insect pest infestation is severs. Basically, application of retardant is to remove squares and small bolls, late in the season to deprive pre-diapausing pink bollworm larvae of a food supply. The hormonal termination of growth can be effectively used where cotton is grown in rice fallow tracts and crop rotation systems.