Chapter 13

USE OF PLANT GROWTH REGULATORS FOR CROP MODIFICATION

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INTRODUCTION

The cotton plant is exposed to a multitude of chemicals during the course of its growth and development. Many of these may alter some phase of the physiology of the plant and could have some effect on subsequent growth and development. The effect of any one chemical may be slight and not be apparent in terms of yield and quality, but the effect could possibly be altered through an interaction with other chemicals or with one or more environmental factors and cause a significant change in growth and development. Efforts have been made in recent years to determine the physiological effect on the cotton plant of several of the pesticide chemicals that are used as standard cotton production practices. In addition, investigations into the feasibility of using synthetic growth regulator chemicals to manipulate the vegetative and reproductive development of cotton have increased significantly in recent years. Much of the earlier plant growth regulator research was reviewed by Guinn (Chapter 12) and, therefore, will not be included in this section.

REPRODUCTIVE DEVELOPMENT

The use of synthetic growth regulator chemicals to improve yield and quality of cotton has been researched by numerous investigators. In addition to the traditional efforts of using chemicals to increase yield through increased boll-set, other approaches such as chemical alteration of plant processes are being investigated. But attempts to increase fruitfulness by exogenous applications of growth regulator chemicals have been less successful than in other areas of growth manipulations.

A regulatory mechanism within the cotton plant causes an unusually large percentage of the fruiting forms to shed, and the plant frequently matures bolls from less than half the flowers produced. The exact nature of this mechanism is not entirely understood, but it could conceivably be either nutritional as suggested by Eaton (1955) or hormonal as proposed by Horowitz (1962). More likely an interplay of both theories is involved. Work by Varma (1978) suggests that the cotton fruit retention:abscission ratio depends on the balance between nitrogen and the endogenous growth regulators, gibberellic acid (GA) and abscisic acid (ABA) within the plant tissue. He reported the GA and ABA levels to be low in retained fruit as compared to abscising ones, and nitrogen levels to be high in retained bolls and low in those abscising. Work by Rogers (1980b) also suggests that the retention:abscission ratio of cotton fruit depends more on the balance between ABA levels and other hormone levels than on the absolute amount of ABA present. Ergle (1958) reported that gibberellins produced taller plants, but caused no effect on agronomic performance. In a similar study, Bird and Ergle (1961) found that cotton cultivars differ in their response to GA_3, and they suggested that cultivars may vary in levels of natural gibberellins. This variability may help to account for the erratic results obtained by investigators in their attempt to improve yields by exogenous applications of GA.

Cytokinins delay or prevent senescence and promote the ability of organs to compete for metabolites (Letham, 1967). Rogers (1981b) made comparative analyses of retained and naturally abscising cotton fruits and found that abscission was negatively correlated with the concentration of cytokinins. Numerous formulations that contain cytokinins are marketed as plant growth stimulants for a wide range of crops. Several of these have been tested for yield enhancement in cotton production, but the authors are unaware of any reports in the literature of significant yield increases resulting from their use. Cothren and Cotterman (1980) tested one such product for two years in Arkansas and found trends toward increased yields in the cytokinin-treated plots, but the differences were not significant. They reported significant decreases in transpiration and nitrogen loss from treated leaves which suggest that cytokinins may alter metabolism of cotton plants in favor of increased yields.

When insecticides are used as test chemicals for plant growth regulation, it is often difficult to distinguish between plant response to the chemical *per se* and response to relief from insect damage; however, there is ample evidence that some insecticide chemicals can have physiological effects on flowering, fruiting and cutout. Hacskaylo and Scales (1959) reported that flower formation, boll set and plant growth were retarded and plant maturity hastened when cotton grown under insect-free conditions was sprayed with dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydroendo-exo-1,4,5,8-dimethanonapththalene) and DDT [1,1,1-trichloro-2,2-bis(4-chlorophenyl)-ethane]. Conversely, plants sprayed with azinphosmethyl /0,0-dimethyl-S-[4-oxo-1,2,3-benzotriazin-3(4*H*)yl)-methyl)]phosphorodithioate/ produced more flowers and more bolls and had a longer maturation period than the controls.

Brown *et al.* (1961, 1962) used multiple applications of toxaphene-DDT, calcium arsenate, and methyl parathion [0,0-dimethyl *0*-(*p*-nitrophenyl) phosphorothioate] to determine insecticide effects on plant growth and development of field cotton. Treatments with toxaphene-DDT increased boll production each year, but a concurrent reduction in boll size during the first year offset the boll number advantage, and yield was not affected. Yield was increased the second year in the toxaphene-DDT plots. Treatments with calcium arsenate reduced boll production and yield in each test. Roark *et al.* (1963) reported no effect on plant growth and development from treatments with toxaphene, DDT, or toxaphene-DDT mixtures. Methyl parathion apparently has no effect on boll numbers or seed cotton yield, but tends to increase average node number of the first fruiting branch; delay square and flower production; increase average boll period; and delay plant maturity (Brown *et al.*, 1962; Roark *et al.*, 1963; Beasley, 1969; Thomas, unpublished).

Major beneficial effects on initiation and retention of cotton fruit were reported by Phillips *et al.* (1977) when field plants in Arkansas were sprayed with chlordimeform [N-(4-chloro-*o*-tolyl)-N,N-dimethyl formamidine]. However, no differences in flowering rate, boll production, or yield were detected in similar studies conducted in a relatively insect-free environment at Stoneville, Mississippi (Cathey, unpublished). Conflicting results have also been obtained from the use of acephate (*O*,S-dimethyl acetylphosphoroamidothioate) to alter plant growth and development (Cathey *et al.*, 1981a). Multiple applications of acephate to field plants in 1977 caused an increase in flowering rate, boll production, boll size and yield. Similar treatments in 1978 and 1979 resulted in no effect on any of the parameters measured. In addition, growth and development of greenhouse cotton plants were not affected by acephate treatments. ^{14}C-labeled acephate, however, has been shown to translocate from treated leaves to all parts of the cotton plant and to accumulate in areas of rapid growth when multiple applications were made (Cathey *et al.*, 1981b). The fruiting forms and plant terminals appear to be the main sinks.

VEGETATIVE DEVELOPMENT

Early attempts to alter plant size were made by various mechanical treatments. None of these ever proved entirely satisfactory, however, and efforts were then directed toward chemical treatments to accomplish the same objective. The plant growth retardant, 2-chloroethyltrimethyl-ammonium chloride (CCC or cycocel), has been used in many areas of the world to significantly reduce plant height. However, significant reductions in yields are frequently reported when this chemical is used. In addition, fiber and seed quality may be adversely affected. Thomas (1964) was able to reduce plant height significantly with spray applications of CCC to greenhouse cotton, but yield was reduced by about the same percentage as plant height. He reported only minor reductions in flowering, but significant reductions in boll-set two to five weeks after treatment. In a more recent study Thomas (1972) was able to reduce plant height by 16 inches without a significant reduction in yield. De Silva (1971) reported that cotton in Uganda responded to CCC with a reduction in both plant height and yield. Reduced yields resulted from excessive fruit shed toward the end of the season. Similar results were obtained in Arizona (Kittock *et al.*, 1974) and in Mississippi (Thomas and Hacskaylo, 1974; Thomas, 1975). Singh (1970) reported that applications of CCC 70 to 80 days after planting retarded growth and increased the number of bolls per plant, boll weight and yield. Sprays of 40 to 160 ppm CCC increased yields 15 to 45 percent. TIBA (2,3,5-triiodobenzoic acid) was used by Thomas (1967) to reduce plant size and dry weight, but the chemical also significantly reduced seed cotton yield. Similar treatments with CCC in the same experiment reduced plant size without affecting yield.

The experimental growth regulator chemicals, BAS 0660W (dimethyl-morpholium chloride) and BAS 0640W [dimethyl-N-(β -chlorethyl) hydronium chloride], caused significant reductions in plant height, increases in early flowering, early maturity, and lint percent (Follin, 1973). These two chemicals were forerunners of the plant growth regulator 1,1-dimethyl piperidinium chloride (also known as Pix® or mepiquat chloride). Under conditions of luxuriant moisture and fertility a 20 to 30 percent reduction in plant height can be expected from treatments with mepiquat chloride (Heilman, 1981). Similar reductions in lateral branch length also occur. Walter *et al.* (1980) found a 22 percent reduction in canopy width of mepiquat chloride-treated plants. Bolls per plant were reduced, but boll weight was increased so that yield was not affected. Conversely, Feaster *et al.* (1980) found that bolls were smaller and yields reduced on mepiquat chloride-treated plants. Erratic yield responses to this chemical were also reported by Briggs (1981) in Arizona. He concluded that environmental factors have a major role in determining the final yield response to mepiquat chloride.

In addition to modification of plant growth and development *per se*, growth regulator chemicals may have effects that indirectly influence production. For example, TD-1123 (potassium 3,4-dichloro-5-isothiazole carboxylate) was shown to cause male sterility in cotton flowers without significantly reducing female fertility (Olvey *et al.*, 1981). This might increase the feasibility of producing hybrid cotton seed. Erwin *et al.* (1979) reported that the growth retardants, CCC and mepiquat chloride, mitigated symptom expressions of Verticillium wilt and increased yield of cotton grown on wilt-infested land. Snow *et al.* (1981) found that boll rots were reduced in mepiquat chloride (Pix®)-treated plots in Louisiana during years of abundant moisture. Boll rot damage in Mississippi was also reduced by mepiquat chloride (Pix®) treatments in 1981 (Cathey and Minton, unpublished).

Yield and quality of cotton might also be affected by alterations in fiber properties. For example, elongation and secondary wall thickening of fibers overlap in time (Schubert *et al.*, 1973), so if the duration of either process is extended, the total yield or the quality of the fiber might be improved. Bhatt *et al.* (1972) reported that low concentrations of cycocel gave coarser fibers without affecting other fiber characters; whereas, higher concentrations increased length and fineness but decreased strength, maturity and yield. Cycocel was also shown to cause a significant number of abnormal bolls with coarser fiber to be produced . Bhatt *et al.* (1972) also found that IAA improved fiber length and fineness and that low concentrations of NAA increased fineness but had the reverse effect at higher concentrations. Gibberellic acid was shown to significantly increase fiber length in one variety of cotton in India (Bhatt and Ramanujam, 1972). In a separate study, however, GA had no effect on any fiber property of another Indian variety (Sitaram and Abraham, 1973).

CROP TERMINATION

A relatively new concept in cotton production in many areas is the use of growth regulator chemicals to induce "cutout" or force the termination of vegetative and reproductive growth. Much of this work was done by Kittock *et al.* (1973, 1974, 1975, 1977, 1979) in Arizona and Thomas *et al.* (1964, 1967, 1972, 1973, 1975, 1979) in Mississippi. The primary objectives of the two groups have been reductions of late-season insect populations and earlier harvest. The chemicals most extensively tested as cotton growth terminators include CCC, TD-1123, Chlorflurenol (methyl 2-chloro-9-hydroxyfluorenal-9-carboxylate), ethephon [(2-chloroethyl)phosphonic acid], dicamba (3,6-dichloro-*o*-anisic acid), glyphosate [N-(phosphonomethyl)glycine], DPX-1840 [3,3a-dihydro-2-(*p*-methoxyphenyl)-8*H*-pyrazolo[5,1-a] isoindol-8-one], 2,4-D [(2,4-dichlorophenoxy) acetic acid], and thidiazuron (N-phenyl-N′-1,2,3-thiadiazol-5-ylurea). Most of these have been evaluated separately, in various combinations, and in sequential applications, and classified as fast-acting nonpersistent and slow-acting persistent (Kittock *et al.*, 1974). The most satisfactory results were obtained with combinations of chemicals represented by both groups, either as a combined treatment or applied in sequence (Kittock *et al.*, 1973, 1974, 1975; Thomas and Hacskaylo, 1974; Thomas, 1975). Chlorflurenol (slow-acting) and TD-1123 (fast-acting) combinations gave the most satisfactory results. Regardless of the chemical or combination used, the optimum time of treatment, in terms of effective crop termination with minimum yield reductions, appears to be sometime between mid-August and early-September.

Thomas and Hacskaylo (1973) found that DPX-1840 was readily absorbed and translocated to stem tips, and retarded growth without serious effects on boll development. This chemical was more effective than CCC in this respect (Thomas, 1972). Similar results were obtained when various combinations of chorflurenol and TD-1123 were applied in late August and early September (Thomas *et al.*, 1979). Leaves, squares, small bolls, and insect populations were significantly reduced with only minimal yield reductions. Hopkins and More (1980) used low rates of the defoliant chemical thidiazuron (Dropp®) to reduce feeding sites and insect populations without adversely affecting yield or quality. The herbicide glyphosate (Roundup®) might also suffice as a crop terminator on cotton. It was shown to inhibit regrowth development for extended periods after application (Cathey and Barry, 1977). In addition to reduced late-season insect populations, significantly earlier harvests may be obtained from some crop termination treatments (Cathey, 1980; Wolfenbarger and Davis, 1976). Sequential treatments of mepiquat chloride, chlorflurenol and TD-1123 advanced harvests in one Mississippi test by 14 days with no significant effect on yield (Cathey, 1980). Similar results were obtained in Texas when combination treatments of chlorflurenol and 2,4-D were used (Wolfenbarger and Davis, 1976). Crop termination and early harvest may also be obtained by the use of high ethephon rates (1 to 2 lbs/acre). When used at these rates, this chemical stops terminal growth, accelerates boll dehiscence and induces abscission of leaves and immature fruiting forms (Singh and Kumar, 1978; Cathey and Luckett, 1980; Cothren, 1980; Cathey *et al.*, 1982).

SUMMARY

The primary objectives of recent plant growth regulator work in cotton production have been: a) improved balance between reproductive and vegetative growth; b) suppression of undesirable late-season fruiting forms; and c) earlier maturity and harvesting. The literature and assessment of unpublished reports indicate that these goals can be realized without serious effects on productivity. The degree of success apparently is determined by choice and concentration of chemicals, timing of applications, condition of plants at time of application and environmental factors subsequent to treatment. Although the attempts to increase the fruitfulness of the cotton plant by exogenous applications of growth regulator chemicals have, in general, given negative results, a considerable amount of success has been attained with growth suppression, abscission of late-season fruiting forms, forced cutout and increased earliness. In addition, physiological effects on cotton plant growth and development have been observed when certain insecticides, fungicides and herbicides were used as standard production practices.