CHAPTER 14

CULTURAL CONTROL

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INTRODUCTION

It is likely that at some moment in the last years of the 1890s, a cotton farmer — perhaps several cotton farmers — in the Rio Grande Valley of Texas, sizing up his experience, reached a persuasive conclusion about a matter of importance. He had had by now several years to examine and mull the matter; surely he regarded his judgement as meaningful, and surely he communicated his conclusions to neighbors. Taking account of what he had seen on his and neighbors' farms, he decided that cotton grown on certain soils, and in certain locations, and that certain cultivars of cotton, were especially vulnerable to damage from the newly introduced Mexican cotton boll weevil, *Anthonomus grandis grandis* Boheman. Entering the Valley probably in 1892, the boll weevil was the beginning of the end for a cotton production era that had run a course largely free of infestations of injurious insects. For a 100 years, acreage of the crop had expanded in this country, and it was acreage farmed with considerable license and leeway. Such was the absence of insect threat that cotton could be cultivated across the southern United States, restricted only by the lack of suitable soils or by deficient rainfall. In no instance had an insect dictated where the crop should be grown, or how it should be grown. The bottomlands of the Brazos and the Mississippi, and the upland spaces of the Piedmont and the Blacklands Prairies, and creek bottoms of Alabama and Georgia and sandy fields grubbed out of thickets of east Texas pines — all were chosen for the crop, although, obviously, the more productive lands were preferred. The boll weevil then would violate an old self-evident truth, making at the same time a compelling statement about how the crop would be grown in the future.

In any case, the Rio Grande Valley farmer who had enjoyed this historical production license took measure of the new and unprecedented situation: on sandy, loamy soils where cotton had always fruited slowly, losses to the boll weevil were often severe; and where cotton was planted in proximity to brushy rangeland, losses were substantially elevated. Aware of the varying earliness among the cultivars grown in his community, this grower noted that cottons that proceeded quickly with vigorous fruiting and rapid boll set produced more cotton in the presence of weevils than the slower-fruiting cottons that were commonly planted. Thus was born, though informally, the beginnings of a control strategy. There was a corollary to his observations: If the likelihood of weevil damage was associated with certain farmer decisions and practices, there were clearly adjustments possible to alter or cancel these; there were immediate, practical changes — cultural changes — that could be made in the face of this new reality.

From this imagined but likely beginning, and from the watershed of broad experimentation that followed by entomologists of the public institutions on all cotton insects, emerged a strategy—cultural control. For many years, until the organic insecticide period of post World War II, the cultural strategy represented the major component of the plan for addressing several of cotton's insects. The efficacy of these chemicals then largely eclipsed the cultural elements, but in more recent times with new understandings and an awareness of the difficulties of cotton insect control strategies built on an insecticide foundation only, application of cultural measures has received renewed attention.

The cultural recommendations of the public institutions that answered the intrusion of the boll weevil were promulgated, roughly, from 1895-1912; and these came to be known as the "Government Method" (Helms, 1980); and pioneer protagonist and advocate of agricultural extension education, Seaman Knapp, set about with on-farm demonstrations to promote this scheme of the entomologists (Knapp, 1911). If the program was given to farmers as a package of steps, the hard reality was that but two of the recommendations were the important elements; and only one of these was, or could be, carried out successfully. The first of these was timely stalk destruction, but its practice for boll weevil management was ahead of the times and usually not followed; the second, the securing of earliness in cotton production by way of selection of cultivar, planting date and row spacing, and through judicious fertilizer use, became common practice and had a powerful effect in mitigating boll weevil damage. These were the heart of the Government Method, and in this chapter we will consider them and other aspects of cultural control.

STALK DESTRUCTION, FIELD SANITATION, HARVEST PRACTICES, TILLAGE AND WINTER IRRIGATION

BOLL WEEVIL

In the fall of 1894, L. O. Howard, the new chief of the Division of Entomology (C. V. Riley had just stepped down) of the United States Department of Agriculture in Washington, D.C., contacted an old friend and erstwhile member of the Division, C. H. T. Townsend (Wagner, 1980). Would he, Howard asked, accept a position as temporary agent for the Department in south Texas where a disturbing situation had only recently developed in cotton? Charles Henry Tyler Townsend jumped at Howard's offer, accepting the position with relish. A man of catholic biological interests, a student of natural history, Tyler Townsend sought a research appointment. And so he accepted, moving briskly to south Texas in a few weeks where he began to examine the developing problem, the boll weevil. He kept Howard apprised during the following months with what were surely alarming reports, and the full substance of his investigation was published the next year in Insect Life (Townsend, 1895). The content of the report was an apocalypse. Analysis of the situation in several of the cotton producing communities near Corpus Christi indicated that the weevil had exacted yield reductions of 30 to 90 percent. Extensions of these figures north and east across Texas, and possibly across all of southern United States where cotton was farmed in a one-crop economy, must have been frightening considerations for Howard and all others privy to the possibilities of the matter.

Research on the boll weevil started with Townsend. Perhaps his significant contribution was the recognition of the need for stalk destruction after harvest to reduce winter carry-over of adult boll weevils. Kill the boll weevils in the crop residue in a field he reasoned, by plowing or burning, and you will have fewer boll weevils to endure the following season. Because the weevil was known to attack only cotton, this tactic was all the more persuasive. Townsend clearly thought that overwintering was restricted to the immediate infested cotton field, unaware that the adults fly throughout cotton growing communities as they seek quarters in many places, especially in the leaf litter of well-drained wooded sites (Isley, 1929). Townsend called for other cultural adjustments, these well beyond the practice of the individual farmer. No shrinking violet, he boldly implored for laws that would interdict cotton farming across a broad fifty mile swath of southern Texas to stop the weevils' northern, and eastern, progress. Politically charged, involving the livelihood of hundreds of farmers, this recommendation had no chance for implementation. Later, as the weevil ranged eastward, states attempted, to little effect, to apply quarantines (Hunter, 1905). The proposed Townsend interdiction, had the Texas Legislature acted or had there been Federal imposition, might have bought, at best, a few years for northern and eastern production — before the cotton free zone was breached by dispersing weevils.

USDA investigations of the boll weevil problem in Texas continued into 1898 — the year the Texas Legislature appropriated money to fund a State Entomologist position at the Agricultural and Mechanical College; the year the insect was well into east Texas. The Division of Entomology withdrew from Texas in 1898, and Frederick William Mally was engaged in the state position (Little, 1960). Without delay, Professor Mally was about this problem of the boll weevil. Launching a triad of effort — research, extension and education — Mally, as he toured south central and eastern Texas cotton growing districts, speaking before farmer groups, arguing and exhorting, extolling early-maturing cottons, grimly demanding prompt stalk destruction after harvest, acquainted farmers and the public with the term "entomology" (Wagner, 1980; Anonymous, 1901). As Townsend, he recognized the value of stalk destruction before frost because this was the "vulnerable period" in the weevil's yearly history. Mally recognized that even in the absence of the practice of early stalk destruction, relatively few adult weevils survived the winter; obviously the additional tier of mortality resulting from early stalk destruction would further reduce numbers (Mally, 1902). He made a judgement about the weevils that survive the winter, and this conclusion, because it apparently was based on Mally's imagination rather than on the facts of experimentation, is rather more remarkable. He sensed that there was some special quality of the weevils that reached the adult stage during the fall, and it was only these insects that could successfully overwinter.

It is credited to Brazzel and Newsome (1959) the discovery of diapause (a physiological reordering that permits survival in a harsh period) in the boll weevil. They demonstrated that boll weevils that are to survive the winter originate primarily from eggs deposited in the late summer-early fall and that these adults are, in several ways, different from the reproducing weevils of summer; they noted also that a feeding period of some days is required by adult weevils for the attainment of diapause, further emphasizing then the need for timely stalk destruction. Later, research (Brazzel and Hightower, 1960; Lloyd *et al.*, 1967; Tingle and Lloyd, 1969; Carter and Phillips, 1973) would measure the pattern of diapause incidence in the insect in the late summer-fall period and the factors that influence its occurrence. Mally, not knowing the term "diapause," and in the absence of the understanding of the phenomenon we presently enjoy, seemed to recognize this difference in the two kinds of weevils that Brazzel and Newsome described. In his 1902 report to the President of the Agriculture and Mechanical College, Mally wrote of the weevils belonging to the "summer brood" and to the "hibernating brood" (Mally, 1902):

> "It is safe to state that a large percent of those which had laid a considerable portion of their eggs before going into winter quarters will either have died during the winter, or perish very early in spring after having deposited a few more eggs. The weevils coming from hibernation quarters in spring and which have laid no eggs the previous fall are the ones which live longest in spring and lay the principal portion of eggs for the first generation of larvae."

He suggests here that diapausing boll weevils lay no eggs prior to entering winter quarters, that these weevils have an entirely different purpose—A conjecture later confirmed (Walker, 1967). As Townsend, Mally was convinced that elimination of boll weevils in crop residue in the immediate cotton field or very nearby, by plowing, burning or grazing, would reduce overwintering. Neither man had appreciated the dispersing quality of late summer-fall boll weevils, that these insects seek out overwintering quarters throughout a farming community, often distances away from cotton fields.

Frederick Mally as Townsend was not a man burdened by reticence. In his report to President D. F. Houston of the College, together with a number of practices that the individual grower should follow to diminish weevil losses, Mally included his critical thoughts on those farmers who had not warmed to his recommendations on prompt stalk destruction after harvest; and he demanded, posthaste, enactment of laws requiring this practice in the fall and the summary means to deal with those recalcitrants who do not see fit to comply. His passion notwithstanding, laws were not passed; increasingly the professor came under fire from a dissatisfied clientele, and in 1902 he resigned (Wagner, 1980). Mally had not given the easy control answers invoked by growers, but both he and Townsend had made the case for stalk destruction. Both had thought erroneously that the total benefit of the practice came from the immediate destruction of weevils that happened to be present when a cotton field is destroyed. The fact that they did not understand that it is the removal of growing cotton that ends the food source necessary for the attainment of diapause that curtails overwintering does not form as a great error however.

Uncomfortable with the progress of the entomologists of the public institutions and feeling the continuing political heat, the Texas Legislature with prodding from the Governor responded again, posting in 1903 a reward of $50,000 for solving the boll weevil problem. This staggering amount (a fortune in 1903 dollars) was to be given to anyone coming forward with a solution (Cohn, 1956). Fiscally chary lawmakers of those times who were knowledgeable in matters of the boll weevil probably lost little sleep over the prospects of awarding the money. As they had half-imagined, the $50,000 was never collected. Apparently the Legislature felt that the partial cultural solution to the weevil soon to derive from the organized research programs of the USDA and state entomologists did not qualify. In the end, none of the numerous (about three hundred) and sometimes harebrained schemes and devices that were submitted as solutions measured up under examination. Each though had been dutifully scrutinized by USDA entomologists who had returned to Texas in 1901, and their findings were made known to a legislature appointed committee, the Boll Weevil Commission. One secret remedy was fuzzily described in a letter from France, from a Dr. L'heureux. A pesticide apparently, the product was "very simple, infallible and little expensive..." and did no injury to plants. And there was more. Applied to human skin, this boll weevil remedy, Dr. L'heureux noted, behaved as a mosquito repellant (Wagner, 1980).

Mally's entomological program had been supported by an initial state appropriation of $5000. Out of that came his salary, $2800, and $2200 remained for research and travel. It was a level of funding that, given the scale and complexity of the weevil problem and the political discomfort that grew from the insect's pillage, may not have been a token appropriation but it wasn't a great deal more. Examined against the well-funded, well-staffed research program of the USDA, research of Texas' first State Entomologist moved along on a shoestring (Wagner, 1980). The Division of Entomology built a laboratory at Victoria in 1902, moving the facility to Dallas in 1905; and as research leader for Texas, chief L. O. Howard chose, in 1901, young Walter David Hunter. The selection was a masterstroke: Hunter, age 26, would move with grace and control through the political thickets created by the boll weevil, establishing credibility in the eyes of growers as Frederick Mally had not; and the considerable progress in the understanding of the "natural history" of the pest that would arise from USDA research. The application of that understanding to cultural strategies, became a testament to Hunter's leadership.

With the eastward advance of the weevil, a USDA research facility was established at Tallulah, Louisiana in 1909. A cotton entomology research program was launched in the state a few years earlier. It was sponsored by the Louisiana State Pest Crop

Commission and under the direction of Wilmon Newell (Little and Martin, 1942; Parencia, 1978). It was during the ten years or so after Mally's departure that the Government Method, in part, was implemented by farmers. The extreme yield losses that Townsend had measured in south Texas in the first years of weevil infestation did not last (Hunter, 1909a); cultural adjustments, largely in the form of early-maturing cottons, had partially deflected the brunt of weevil attack; and reductions in cotton yields because of the boll weevil fell to ten percent or less. Although weevil losses were greater as the pest moved into the higher rain zones of the eastern United States, they were not as severe as that foreshadowed in the Townsend report (Brown and Ware, 1958a). The fast-fruiting cottons had made the difference. But, if farmers had willingly and successfully changed one practice, from slow-fruiting cultivars to early-maturing ones, they could not bring themselves to assiduously practice prompt stalk destruction. There were, as we shall see, reasons for this.

Considerable evidence accrued during the early 1900s, expanding the understandings of boll weevils and hibernation, making an ever stronger case for the cultural operation of stalk destruction. However, entomologists still did not understand that potential overwintering weevils in the late summer-fall season disperse in all directions and for some distance from old cotton fields as they seek all manner of places to protect themselves from winter climes (Hunter, 1904a). Destroying weevils in or very near to cotton fields before frost was thought to lessen overwintering. USDA entomologist W. D. Hunter repeated the earlier advice of plowing out cotton (to the roots), wind rowing and burning, adding a description too of a stalk cutter that could be pulled by either horse or mule — "a wheeled cylinder provided with oblique knives." Experiments reported by Hunter (1907) made even a stronger case for early stalk removal, showing that weevils removed on different fall dates from cotton and caged on hibernation media survived in greater numbers as they were caged later in the season. It logically followed that if stalks were cut and destroyed at dates corresponding to those of the hibernation cage tests, similar hardship would be placed on weevils seeking to overwinter. By 1909, the strong dispersing ability of the hibernating weevil seems to have been recognized. "They fly from cotton in the fall in all directions," Hunter wrote (Hunter, 1909b), adding that the insect could fly forty miles. Hunter and Pierce (1912), taking a backward glance, assessed the weevil and the success of research to combat it, contrasting the extreme losses to the pest in its first years in Texas with contemporary and improved yields. They noted again the persuasion of the hibernation cage study data that, over a period of years, had argued for early stalk destruction — the earlier weevils were removed from cotton in the fall, the greater the winter mortality. For example, about 0.3 percent of the September weevils survived against a 10 percent survival of weevils caged in December, a pattern of survival not adequately explained until the research of Brazzel and Newsome. September survival was low because the incidence of diapause was low, that of December greater because of the higher incidence of diapause. The writers referred to a stalk cutter newly invented by the State Crop Pest Commission of Louisiana, and the USDA entomologists obviously had pinned hopes on the device. Unlike the "wheeled cylinder..." previously mentioned, the contrivance was a "V" shaped sled, each side of the V armed with a sharpened blade. An implement of some bulk, the rig was to be pulled, instructed its inventors, by two horses, hitched, not side by side, but in tandem. Plans that might be used for on-farm construction of the V cutter appeared in a circular of the Commission (Newell and Dougherty, 1909).

Certain field experiments and observations averred the findings of the hibernation cage work. Hunter wrote of the experience in Calhoun county of Texas in 1906 where 400 acres of isolated, weevil infested cotton were plowed up and burned in the first ten days of October. The following year a series of examinations on cotton planted there established a much reduced weevil infestation and high production. A check field was infested early, incurring considerable lint loss to the pest (Hunter, 1912). Observations were made by Wilmon Newell in Louisiana on the effects of an early killing frost, November 13, 1907, on weevil infestation in cotton of the area during the following year: It was considerably reduced, compared with infestations in cotton in south Louisiana (Newell, 1909a). By 1912, it seems, experience and a body of data had made a case for the removal of cotton stalks by early October. Hunter put it well, this need for stalk destruction, in the title of a circular of the Bureau of Entomology: "The most important step in the cultural system of controlling the boll weevil" (Hunter, 1904a).

As important as the tactic seemed to cotton entomologists, the truth of the matter was that farmers found every reason not to follow the recommendation. As Helms (1980) wrote: "Farmers shunned most the aspect of the cultural system that entomologists claimed brought the highest degree of control." In the first place, hand-harvesting of cotton was a protracted affair, often extending late in the fall and past the time of early October when stalk destruction was called for. Too, the economics of the crop compellingly demanded that every last harvestable boll be harvested; and the lure of that occasional event, a "top crop," as infrequently as that occurred, served to counter the earliness theme itself. An official of the Texas Agricultural Experiment Station of those early years estimated that less than one percent of Texas farmers practiced the recommendation (Helms, 1980).

Stalk cutters were available, but their costs were prohibitive to many farmers; and in the event that a farmer owned one, he found it an inadequate tool for cutting tough, resilient, green cotton stalks in October (Wilkes *et al.*, 1962). On the other hand, should he wait into the late fall or early winter after a freeze had killed the stalks, dried them, made them brittle, stalk destruction was a far easier chore. But, of course, by then it was too late; weevils had already prepared for hibernation and left the field. In those instances when a grower did destroy stalks with some sort of a cutting implement, it did not follow that the plants' roots could always be immediately plowed out — a practice needed to prevent regrowth. Perhaps dry, hard soils would prevent the plowing operation after stalks were cut; and when plowing could be started, the slow mule drawn operation naturally worked against a quick removal. And, perhaps, a human element, the propensity to rein up and take one's ease after a job is seen to be over — and indeed the harvest of that last lock of cotton on one's farm had a ring of finality to it — was factored into the southern cotton farmer's unwillingness to assiduously tend to stalk destruction. For years, following harvest, growers had plowed out their cotton stalks, at their own pace, at a time of their choosing. Now they were being asked to do something else.

The early stalk cutters were inadequate to deal with green cotton especially in those regions where stalks were large; and even the first modern rolling stalk cutter (Brown and Ware, 1958b), an implement introduced in 1925 that could be used behind animals or, in rare instances, tractors, lacked the engineering capability for cutting green cotton stalks over a range of conditions. There must have been hopes though for improved stalk cutting where the implements were tractor drawn; in any event, the Ford Motor Company, in the 1920s, saw cotton stalk removal as a sales opportunity for their newly introduced Fordson tractor — they even made a movie about it with the title: " Where the Fordson Shines: Beginnings of the Systematic Extermination of the Enemy of the South: Boll Weevil" (Helms, 1980). Ford figured to carry out this systematic extermination using the Fordson to pull a cutter.

If the cultural practice of stalk destruction was in the main ignored, there were a few examples where concerted efforts brought stalk clean-up in areas of some scale. Little and Martin (1942) noted that the strategy was more ordinarily observed on the coast (presumably the Texas Gulf coast) because early planting and earlier harvest happened to accommodate its practice. Also, Gaines and Johnston (1949) described the organized stalk destruction program that took place in Williamson county of Texas in the late '40s and the positive reductions in weevils the next year. Included was an account of various levels of farmer compliance in stalk destruction in the Rio Grande Valley and the resulting effects on boll weevil infestations the following seasons. War, patriotism and propaganda even have had a place in cotton stalk destruction: Concerned not so much with boll weevils as pink bollworms, *Pectinophora gossypiella* (Saunders), cotton interests of the Rio Grande Valley during World War II years and a high pitch of propaganda in local newspapers placed farmers who were not attentive to stalk destruction and the unpatriotic on the same shelf (Walker, 1984). Everything Americans did or did not do in those years had something to do with winning the war, and that included cotton farmers.

In another instance, stalk destruction and allied practice achieved such a concert of appliance that, if it resulted in a victory over overwintered weevils, it was literally a Pyrrhic one. During the 1920s, growers of Greene county Georgia took the early burning recommendation to heart, extending its application not only to cotton fields but to woods, hedgerows and terraces. Weary of claims for burned down houses and farm buildings, insurance companies in the mid-'20s refused to write rural policies for the county (Helms, 1980).

For all of the preceding, yearly, effective, areawide practice of stalk destruction, as W. D. Hunter had imagined it, did not come about until well after World War II. If there was a single reason, we believe it rested with the lack of a specific farm implement: a stalk cutter of appropriate design, and power, to cut green cotton stalks efficiently over a range of stalk sizes. The old rolling stalk cutter, whether powered by mules or early tractors, operated largely as a consequence of the weight of the implement or the sharpness of its cutting blades (Wilkes *et al.*, 1962). Its efficiency arose, obviously, apart from any external power source other than the speed at which it was drawn. An effective stalk cutter awaited mechanization in cotton; and during the '30s, through the first years after World War II, mechanization became, indeed, fact (Brown and Ware, 1958b). Stalk cutters were developed that functioned not just because they were equipped with a set of stalk cutting blades — they cut stalks efficiently because power could be transmitted from the engine of the tractor to the cutter. The first of these machines was powered by way of a chain or belt drive (Smith and Jones, 1948), but the rapid development and standardization of power take-offs on tractors after World War II permitted new and efficient design in stalk cutters: the horizontal rotary blade cutter (Smith, 1964). Further improvements arrived with the flail cutter, a machine that chops the entire plant into small pieces. The rotary cutter, a simpler machine, however, is the more common choice today. By the late '50s, rotary cutters were common implements for farmers: For the first time, stalk removal in cotton fields, whether in Texas or Mississippi, could be addressed with ease. Rotary horizontal stalk cutters as they came to be used in increasing numbers had to have decreased numbers of boll weevils overwintering; but they received little formal credit. They were being used now because cutters had become part of a well-managed farming operation. Farmers were cutting stalks out, not so much because of boll weevils, but because it was the first step in a series that would lead to seed bed preparation for next year's crop.

Another practice, mechanical harvest, came soon after World War II that would accomplish some of the goals of stalk destruction but before the act of stalk destruction. Stripper and spindle harvest, and the harvest-aid chemicals that are required for their operation, necessarily has levied another level of mortality on boll weevils that are to overwinter (Cleveland and Smith, 1964; Summy *et al.*, 1986); and today the machines are used to gather the entire United States crop. Mechanical harvest with spindle pickers has eliminated the protracted hand harvest period that had once left standing cotton in the field late in the season, and stalks can be destroyed earlier. But even before stalk destruction, the required use of defoliants, applied before harvest, will have caused leaves and small fruits to shed. In effect, preparation for harvest, the picking operation itself and finally stalk destruction are an interruption of considerable magnitude in the usual seasonal order of boll weevil diapause. One or two harvests are made where spindle pickers are used. In the March planted cotton in the Rio Grande Valley of Texas, good managers can destroy stalks in August, an operation early enough to reduce sharply numbers of overwintered weevils. Recent improvements in earliness of new cotton varieties of the eastern United States (a topic discussed in a later section) should allow harvest and stalk termination in October in many instances, a time early enough to affect weevil overwintering.

Practiced in large parts of Oklahoma and Texas, stripper harvest can exact a heavy toll on boll weevils that might otherwise seek to overwinter. The desiccant arsenic acid is applied to cotton before stripper harvest in the Blacklands and Lower Gulf Coast of Texas; and the chemical kills all leaves, drying squares and small bolls, swiftly eliminating food for weevils that might overwinter. A single harvest gathers the entire crop.

Shredding is often accomplished in late July in Texas coast cotton, in early September in the southern Blacklands of Texas. Removing cotton stalks early in these regions, and that effect on overwintering weevils, is an important determinant of the reduced insecticide usage there (Anonymous, 1981).

Certain new harvest-aid chemicals, ethephon (Prep®) and thidiazuron (Dropp®) hasten the opening of mature bolls and cause small, immature green bolls to shed from the plant, allowing still earlier harvest. In addition, the chemicals reduced the number of weevils emerging from collected squares and bolls (Bariola *et al.*, 1986). Thus, these products are an additive to the cultural management of the pest that present harvest procedures bring. Modern harvest technology followed by stalk destruction then, unimagined in its present detail by Frederick Mally or Walter Hunter, has effected, variously, the tactic these entomologists roughed out more than 80 years ago.

The powerful force of stalk destruction followed by stubble plow-out in suppressing boll weevils in the cotton system can be witnessed in the current yields and insecticidal use patterns of farmers participating in the integrated pest management program of Williamson county, Texas. Under the auspices of the Texas Agricultural Extension Service, a county agent-pest management professional supervises insect management for a number of farms in this Blacklands' location where the crop is grown dryland. Cotton is stripper-harvested in early September, and stalk destruction and plowing follow. Historical yields, 1928-1939, for Williamson county averaged 162 pounds of lint per acre. The average yield over the seven years 1983-1989 was 513 pounds of lint. Essentially all growers apply early season applications for thrips, *Frankliniella* spp., overwintered boll weevils and cotton fleahoppers, *Pseudatomoscelis seriatus* (Reuter). C. G. Sansone, Extension county agent-pest management, compiled the following information on late-season insecticide use by participating growers for boll weevils, bollworms, *Helicoverpa zea* Boddie, and tobacco budworms, *Heliothis* virescens (F.):

	Number of late-season treatments						
	1981	1982	1983	1984	1985	1986	1987
Bollworms-budworms	0.9	0.8	0.4	2.2	1.0	1.5	1.6
Boll weevils	1.2	1.4	0.6	0.2	0	0	1.0

Obviously, late-season infestations of weevils are a small matter for Williamson county growers. Assiduous attention to stalk destruction and plow up are accountable in large part.

We have considered in this discussion cultural actions that are performed to reduce numbers of overwintering boll weevils, of diapausing adult weevils. These actions deny food sources to the special adult weevils that are to diapause. But boll weevils can overwinter as immature and unfed adults enclosed in late cotton bolls (Bottger *et al.*, 1964; Bergman *et al.*, 1983), and a small percent can live to infest squares the following years. That is, these adults that emerge in the spring have not fed, and will not feed, until the squares appear in the new crop. This problem has occurred in Arizona stub cotton fields, (cotton not plowed out at the end of a growing season but cotton allowed to remain in the field for next year's crop). Stub cotton provides a source for infestation in not only the stub fields but also in adjacent cotton farmed under normal culture. Practiced off and on in Arizona for years, contributing to the pink bollworm problem, stubbing of cotton is now prohibited in Arizona (Moore, 1985). Unfortunately, weevils also overwinter in Arizona as typical diapausing adults; and these establish, in cotton, as they do in the East, beginning infestations in the spring. Stalk destruction, which is not required of growers until mid-winter in Arizona, could not be expected to levy the degree of population management that a September shredding brings in Texas.

As in Arizona, weevils survive during the winter in bolls on undestroyed stalks in scattered cotton fields in the Rio Grande Valley of Texas. Moreover, the mild winter here, the lack of freezing temperatures in some years, sometimes allows cotton in these unattended fields to fruit through the winter; and weevils springing from such locations become a serious threat (Norman *et al.*, 1984; Summy *et al.*, 1988). A few unshredded fields or fields that have regrown after shredding become a source of inoculation for considerable acreage in the following growing season. Although there are September stalk cutting and plow down laws for pink bollworm management in the Valley for years(Allen *et al.*, 1985), scattered fields have remained unattended every year, these influencing nearby acreage. Recently, a new stalk destruction law (The Boll Weevil Control Act) was passed by the Texas Legislature. Under this law, stalk destruction by September 1 is now required for the Valley.

PINK BOLLWORM

In 1916, the chilling experience of the boll weevil fresh in everyone's memory, the United States Department of Agriculture considered the ominous development that only recently had occurred in Mexico. The pink bollworm, an insect pest of cotton in different world regions, had entered the country in 1911 and by 1916 was bringing damage to the Mexican crop. In view of the measures that were soon to follow in the United States, it is apparent that the insect was regarded in 1916 as a manifest threat to cotton — all cotton grown in this country. Taking no chances and prepared to act, the Department by now had the authority to deal with such a threat by way of newly passed quarantine legislation; and the Federal Horticultural Board could execute this authority (Hunter, 1926). Certainly, contingency plans had already been drafted by 1917; and the quick events that reeled off in succession in the autumn of that year justified all of the concern, all of the attention.

Infestations of pink bollworm appeared in a field of cotton near Hearne, Texas in the fall of 1917, a location receiving about 40 inches of rain per year; not many weeks later, additional infestations were noted in southeast Texas where annual rainfall averaged about 50 inches. Typical of United States rainbelt cotton, these production areas with their pink bollworm infestations now, represented the gravest of portents. Analysis of the situation incriminated infested cottonseed imported from Mexico (Hunter, 1926). Armed to deal with such a situation, the United States Department of Agriculture and the Texas Department of Agriculture, in full cry, worked to eradicate these infestations; and they did. The operation was a large, labor intense effort. A force of 500 was organized, its activities directed toward destroying all cotton plant products in the localities: seeds, fallen lint, burs, stalks, bolls, cotton refuse about gins — anything that remained after harvest and that was related to the cotton plant. Sixteen hundred acres of cotton at Hearne and over 7000 in southeast Texas were subjected to this effort in the fall of 1917; and the following year and for additional seasons, no cotton was permitted to be grown in the locales of the infestations. For example, an area six miles in diameter was denied the crop at the Hearne site following the clean-up. And that prohibition was to continue for several years. The eradication clearly was as successful as a political achievement as it was as a biological success. Shortly, other rainbelt infestations were detected in Louisiana, and eradicated (Noble, 1969). Underlining the vulnerability of the insect during fall, these several eradications made, in time, a positive statement on the cultural management of the pink bollworm with, at least, some of the eradication tactics — should it ever become permanently established. In not many years it had.

As with the boll weevil, the diapausing stage (last larval instar) of the pink bollworm represented a weak link; as with the weevil, stalk destruction (and field sanitation) could be used, and even more effectively, to manipulate downward numbers of the pest overwintering. The special realm of the overwintering larvae necessarily makes them vulnerable to cultural measures, limited as these diapausing individuals are to the immediate cotton fields, to implements transporting cotton products and to cotton gin residues. They cannot, as the boll weevil, disperse by flight to overwinter in scattered sites remote from man's actions. Pink bollworm larvae overwinter where cultural procedures can be applied. Unlike the weevil, there are a number of hosts other than cotton; but with the exception of cultivated acreage of okra, it is cotton that provides the important matrix for winter survival (Little and Martin, 1942). The success of the rainbelt eradications, notwithstanding, there is considerable doubt in our minds that the insect would have ever achieved and maintained pest status in the colder, wetter rainbelt production areas of the United States where the eradications had been so effective. But, of course, at a time when public figures were still reeling from the experience of the boll weevil, and when there was less known about the pink bollworm, it is understandable that these eradication programs were conducted. Since those times, infestations have briefly appeared in rainbelt cotton and northwestern cotton of Texas only, in the absence of Draconian quarantine measures, to disappear (Noble, 1969). But for cotton of the southern and warm tip of Texas, and for western desert production, it has been another matter.

The pink bollworm in the years after the Hearne eradication did establish in the near tropical Rio Grande Valley of Texas and, with the exclusion of the San Joaquin Valley of California, the western United States. But, despite the relative nearness of infested cultivated cotton in Mexico, it required years for this to happen. Various quarantine measures slowed its advance. Although the pink bollworm was first detected in Arizona in 1926, for example, much of the production region was held free of injurious infestations; and it wasn't until the early 1950s that the entire state was placed under quarantine (Noble, 1969). The series: Annual Reports of the University of

Arizona, College of Agriculture and Agricultural Experiment Station, 1936-1950, gives the insect little attention. Texas' Rio Grande Valley remained as a fastness from the pink bollworm until 1936, and not until the early 1960s did the southern valleys of California become infested. Quarantine procedures and clean-ups were instrumental in delaying the insect.

The success of the early quarantine and eradication programs had made the case for cultural management of the pink bollworm at the farmer level, and with the 1930s came the beginnings of definitive research on the biology of the insect, and the new understandings that followed together with new technology would make even a more robust argument for the application of cultural measures for the management of this insect.

In 1927, the United States Department of Agriculture established its first laboratory in the United States for pink bollworm research , locating the facility at El Paso. (Earlier investigations, beginning in 1918, had taken place in Mexico.) Experiments in cooperation with the Texas Agricultural Experiment Station were carried out near Castolon, a location on the Rio Grande in the Big Bend country of Texas; and in 1927 a laboratory was opened at Presidio, a remote Texas town on the Rio Grande. Sub-laboratories were put in operation by USDA at other sites as infestation warranted, and one of these, at Brownsville, was elevated to headquarter laboratory status in 1941. Responding to sudden increases in infestation levels in Texas in the early '50s, programs were expanded in 1952; and these were once again a joint effort of USDA and the Texas Agricultural Experiment Station (Noble, 1969). The record of understandings of the pink bollworm derived from the research programs of these agencies across the years is indeed laudable, and much of the progress directed the formation of cultural management strategies. Diapause, the understanding of it, is a case in point.

The appearance of overwintering or diapausing pink bollworm larvae, individuals known as "long cycle" larvae by the entomologists of the 1930s, was first thought to occur because of the influence of the moderating temperatures of late summer-fall (Busk, 1917). They were called long cycle because the insects would remain in the last larval instar in cotton bolls, usually in the seeds of the bolls, through the winter until spring when they would pupate with adult moths later emerging. It became apparent to researchers that the appearance of the long cycle or diapause condition could first be seen in September: About 50 percent of the larvae in open cotton bolls was noted to be in diapause then (Owen and Calhoun, 1932). Although temperatures of early September in Texas often differ little from those of August, temperatures were still commonly thought to be the effectors of this September diapause. Establishing that diapause seemed to be initiated in September eventually became the opening argument for the seasonal timing of regional stalk destruction programs. The reduction of overwintering by pink bollworm larvae ideally would be achieved if cotton stalks could be removed before diapause was prompted in the pest, and it was this rationale that specified September as the month for stalk destruction in the Rio Grande Valley (Curl, 1949).

Understandings broadened as data accreted during the course of research. Chapman and Cavitt (1937) established that earliness of fruit removal from cotton stalks influenced negatively the numbers of larvae in soil beneath the plants; where plants were denuded of fruit on October 1, fewer larvae were recorded than when the stripping process was delayed until November. Other investigations showed that the large majority of the long cycle larvae survived in cotton bolls, although some did exit bolls to burrow in soils, later to form hibernacula (for protection in the winter) (Fenton and Owen, 1931). Studies of Fife *et al.* (1947) that measured the survival of the pest in cotton bolls collected on different dates showed that winter survival of the insect for August bolls was 0.4 percent, in October bolls it was 25 percent.

Other experiments assessed the influence of winter moisture on the time of spring emergence of adults. Moisture hastened pupation and early moth emergence (Chapman and Cavitt, 1934). Other studies measured the effects of tillage and irrigation, winter irrigation and deep plowing reduced survival (Isler and Fenton, 1931). From the foregoing, and from other research, stalk destruction, field sanitation, tillage and winter irrigation (gin sanitation too) were framed into cultural programs for the pink bollworm; and, evidently, for many years these were successful for the management of the pest in the infested areas. For much of the early period of pink bollworm infestations to the 1950s, it should be remembered that growers lacked efficient stalk cutters. Although another agency of control, the organic insecticides of post World War II, was given wide currency in the first years of the 1950s for all cotton insects, an outbreak of pink bollworms throughout much of central and north Texas happened then, this despite the new chemicals. Expanded research programs were quick to follow (Noble, 1969), and they brought a larger comprehension of diapause and the pink bollworm mortality factors that man could impose.

The imperfect understanding of the pink bollworm seasonal diapause was soon given clarity. Lukefahr (1961) tied the appearance of the condition to photoperiod, the length of daylight hours; and Adkisson *et al.* (1966) demonstrated the precision with which the insect cleverly reads the decreasing hours of daylight in the days of late summer and into the fall, in increments of fifteen minutes even, translating these messages purposefully into a higher incidence of diapause as each few days pass. This line of investigation revealed that the first diapause actually arose in larvae that originated from eggs deposited in the last week of August; and from eggs laid at September's end, a cohort of larvae would follow containing 70 percent diapausing individuals.

The effects of harvest-aid chemicals on overwintering in the pink bollworm were researched. When defoliants and desiccants were used at the propitious (favorable) time, the occurrence of larvae in the overwintered state could be greatly reduced. Applied August 22, these chemicals reduced diapausing larvae in cottonseeds about 85 percent over counts in check plots; that is, there were about 12,000 larvae per acre in diapause in the defoliant-desiccant treatments, about 97,000 in the control. Delaying application until October 5 allowed for an enormous increase in diapausing individuals, and near 132,000 per acre were recorded. The chemicals at this later date still effected about a 26 percent reduction over numbers in the controls (Adkisson, 1962).

Decreasing day lengths of late summer-early fall, unlike the inconsistent temperatures of the same period, form as unvarying signals: constants at the same time every year for late infestations of pink bollworms as the message to diapause is comprehended by the insect. Understanding the precision with which day length times diapause in the insect removed all uncertainty and argument about when the crop should be brought to end by the harvesting process — harvest aid chemicals, harvest, stalk destruction and plow up. If these measures are brought to bear in mid-September, wintertime survival will be curtailed in a significant way — primarily because the cotton food source is destroyed before a high proportion of the insects are in diapause. Delay the harvest process until November, and one has guaranteed diapause to the insect.

So destroying cotton stalks before the pink bollworm receives the short day cue to diapause exploits a vulnerable place in the life history of the insect; but even when this practice has been delayed and the condition in the larvae already triggered, research showed that modern stalk cutters, rotary and flail, destroy not only cotton plant parts but also larvae in cotton bolls, reducing consequently the overwintering diapausing population (Wilkes *et al.*, 1962). The flail machines in this regard are superior. Also following the stalk cutting-shredding, moldboard-turning of the soil to a depth of 6 inches, followed by listing, destroys many overwintering individuals (Noble *et al.*, 1962). And, if these practices are followed in desert regions by winter irrigation, even greater reductions accrue. The earlier these tillage operations, the greater the effect; an October practice reduces overwintering more than one of January (Watson *et al.*, 1974). Adding to the mortalities has been the contribution of the harvest-aid chemicals ethephon (Prep®) and thidiazuron (Dropp®). Bringing rapid boll opening and the shedding of immature bolls, applications of these compounds also reduce numbers of diapausing larvae. Obviously, the stubbing of cotton that was once allowed in Arizona provided wintering pink bollworms largesse: The cotton stubs were a refuge for late bolls carrying the pest, and these insects escaped the mortalities induced by plowing and listing (Bergman *et al.*, 1981).

Estimates of certain mortalities and their accumulation that man, through cultural procedures, can levy on the pink bollworm have been calculated (Graham *et al.*, 1962). In this example, stalk destruction is carried out during mid-September when 30 percent of the insects have taken the day length signal to diapause:

Mortality factor	Percent survival after mortality factor
Diapause	30
Harvest	30
Shredding	40
Bolls are left on soil surface until April 15 (squaring date)	1.18

Combined survival is 0.04 percent of the September population. That is, from a larval population of 4,000 larvae in September, less than two are calculated to survive to the adult stage to oviposit in cotton the following April.

Planting and stalk cutting dates for pink bollworm management long have been under the authority of the state departments of agriculture. For example, the Texas counterpart presently sets stalk cutting and plow up by September 25 for the Rio

Grande Valley, a date, if observed by growers, certainly early enough to harshly restrict overwintering (as we noted, a new stalk destruction law recently has been passed in Texas for management of the boll weevil and earlier stalk destruction, September 1, is now required for the Valley). Cotton of the El Paso Valley is allowed to stand until February, long past the time of major pink bollworm diapause (Allen *et al.*, 1985). However, unlike the warm Rio Grande Valley, low winter temperatures often occur at El Paso, bringing greater winter mortality to pink bollworm larvae. Benefiting from a long production season, Arizona has been reluctant to impose stalk destruction dates that are contrary to the opportunities for high cotton yields that are seen by growers to go hand in hand with the long season. Hence, a mid-winter stalk destruction prevails. For another western area, the Imperial Valley of California, there has been a recent change of heart. Accommodated by a warm and long production season, and known for its high yields, the Valley in recent years has lost acreage to the companion difficulties of insecticide resistant major cotton insects, secondary insects and mites, and the onerous expense of the insecticides required to answer the pest challenge. During the last ten years cotton farming has declined 120,000 acres (Anonymous, 1988). The mid-winter stalk destruction time established for the Imperial Valley has allowed abounding overwintering of the pink bollworm, and insecticides for the control of the pest have commonly triggered infestation of bollworm and tobacco budworm and other secondary pests. Until recently, growers have not been agreeable to crop termination procedures that would meaningfully go to the center of the problem; a September harvest practice (which would bring reductions in pink bollworms) has been viewed as unrealistic for their yield priorities. That, as late, has changed; a grower referendum has approved the requirement for the application, by September 1, of a preharvest defoliant, this to be followed by prompt harvest and stalk destruction and plow up by November 1. Such a program, if followed through, could ease the expense and difficulties of insect control in the cotton in the Valley. Though stalks would not be destroyed here in early September, the harvest-aid chemicals and the subsequent harvest (and the stalk destruction to follow) will certainly reduce numbers of diapausing pink bollworm.

ESTABLISHING EARLINESS

GENETIC EARLINESS

Although prompt stalk destruction for weevil management was commonly viewed with disdain because of the impracticality of a mule powered operation, early-producing cultivars that had arisen out of the genetic variability of the planted cottons of the 1800s quickly were seized upon as a means to cut losses to the pest. Within four years after the entry of the weevil, Howard (1896) recommended that farmers plant early-maturing cultivars, and the wisdom of this recommendation was confirmed shortly by other agricultural scientists (Bennett, 1904, 1908; Mally, 1902; Newell and Rosenfeld, 1909). To appreciate the genetic variability that provided cotton producers with this timely means of limiting losses to the boll weevil, one should consider the types and origins of upland cotton being grown in 1892; remember also that scientific development of cultivars of any crop awaited, in the early 1900s, the rediscovery of Mendel's laws. Yet, in the absence of these laws, progress in cotton "breeding" was already being made.

Over the time span covered herein, we will use the term "cultivar" to denote a commercially grown genotype of cotton, realizing that the term "variety" was in vogue until about 1970. The reader should be aware that most cultivars, if not all, from colonial days until probably 1915 or so were not pure lines but rather mixtures of several genotypes, and probably still segregating for others.

In the late 1700s, only two types of cotton were grown on the upland or interior portion of the United States. These were Georgia Green Seed, a cotton introduced to the coastal states from the West Indies by botanist Philip Miller, and Creole Black Seed, which was grown in the lower Mississippi River Valley. The French had brought in the latter about 1730 (Moore, 1956). Lacking a range of useful genetic variability, these cottons likely would not have furnished the kind of germplasm needed in developing the more productive and adapted cultivars that shortly were to be demanded as cotton began its spread from the uplands near the Atlantic coast on to the west. Fortunately, another source of germplasm was soon to appear; and its entry was a new turn for the crop. At no time was that turn more significant than it was in the first years of boll weevil infestation.

Walter Burling, a Mississippi planter from Natchez, traveled to Mexico in 1806 officially to mediate a boundary disagreement between the Spanish territory of Mexico and the Louisiana Territory, a dispute that had kept both sides uneasy throughout the year. To this end, Burling sought and was granted an audience with the Viceroy of Mexico, Jose De Iturrigaray. Following discussions on the dispute, Burling, on a matter of personal importance, opportunistically requested seed of a certain cotton that he had heard of that was grown by Indians of the Central Mexican Plateau. Viceroy De Iturrigaray denied the request. One can only surmise that official Spanish policy was not to part with national resources such as crop plants; at least not to allow their exportation to a territory that had been owned by their traditional rival, France, only three years prior. However, Burling was invited to dine with the Viceroy that evening. After a hardy meal and probably several glasses of wine, the Viceroy became quite cordial, insisting that Burling return to his home in Mississippi with a personal gift "Mexican dolls." The gift was presented in such a manner that Burling could not mistake its meaning; and so he returned to Natchez with dolls, the exact number being unknown, filled with contraband cottonseed (Weiler, 1976). The effects of those seeds were immediate and continuing. If the benefits of Burling's surreptitiously carried germplasm began at once to influence the course of cultivar development, it was the benefits of that same germplasm compounded by selection and outcrossing for the next eighty years that would lead the cotton industry from the weevil disaster.

The following year Burling gave the seed to a friend, William Dunbar, who apparently had received, or shortly would receive, favorable reports on the Mexican fiber from textile experts in England. Between 1807 and 1810, Dunbar increased the contraband seeds to over 3,000 pounds of ginned cottonseed. By 1820, this Mexican introduction had outcrossed with both Georgia Green Seed and Creole Black Seed. Apparently the 1806 introduction was known as Mexican Hybrid, Mexican Highland Stock, and probably by several other names. History suggests that other introductions of the Mexican cottons were made in the early 1800s; however, definite proof is sometimes lacking. The appearance of the Mexican phenotype in Georgia and the Carolinas for instance, about 1825, could have originated from seed of the 1806 introduction. Aside from seed brought by returning United States soldiers from the Mexican War of 1847-48, the historical record notes one other introduction of the stock, this by the Wyche brothers about 1857 (Ware, 1951). When the brothers emigrated from Germany in 1853, one went to Algeria and the other settled in Georgia. In 1857, the brother in Algeria sent a package of cottonseed, apparently of Mexican descent, to the brother in Georgia.

The act of nature in the intermixing of Georgia Green Seed, Creole Black Seed, and the Mexican introduction(s) brought a wellspring of variability that in time yielded extraordinary breeding opportunities; and with the help of Dr. Rush Nutt of Rodney, Mississippi and Mr. Henry W. Vick, son of the founder of Vicksburg, Mississippi, each using different selection techniques, two original cultivars arose — Petit Gulf, developed by Nutt, and One Hundred Seed, developed by Vick. As one would expect, these two cultivars were dispersed across the lower Mississippi Valley and the southeastern United States and renamed many times. Without organized plant breeding efforts and in the absence of widespread use of isolation or selfing techniques to maintain purity, outcrossing, in effect, had resulted in many local or native cultivars. The growth in the number of supposed cultivars was such that during the 1840s, Martin W. Phillips, a seed producer in southern Mississippi attempting to bring order to the trade and move beyond salesmanship and claims, conducted cultivar trials and made the results available to surrounding farmers. These trials may have furnished the first unbiased data of this kind in cotton. According to Brown (1938a), fifty-eight cotton cultivars were grown by 1880, 118 by 1895, and almost 400 by 1907. Tyler (1910), however, identified over 600 cultivars in 1907. It is evident then that a large amount of natural crossing between Georgia Green Seed, Mexican Stock, and Creole Black Seed had resulted in astonishing variability in the cotton being planted at the time of the boll weevil; and it was that diversity that had already permitted, through earlier selection efforts, the development of faster-maturing cottons. By 1900, early maturing cottons had been bred specifically for cultivation in the northern extremes of the Cotton Belt.

The immediate acceptance of the recommendation that farmers grow early-maturing cultivars allowed farmers to survive the onslaught of the pest from Mexico, although there were still yield losses. It is logical that many south Texas farmers, from their own experience, had already observed that cotton fields that fruited quickly, or the earliest-fruiting cottons, or even areas within fields that fruited early, produced more cotton. Surely, Professor Mally made the same observations in growers' fields or had visited with farmers who had had this experience. Perhaps it was this obvious advantage that had prompted him to conduct field evaluations of several cultivars that varied in the earliness quality, and the selection of an early-maturing cotton was high on Mally's list of recommendations to growers (Mally, 1902). The first published recommendation that farmers plant earlier-maturing cultivars was made by L. O. Howard (1896). Howard may have been aware of the early cultivar Dickson, which was being planted in eastern Texas by 1896. This cultivar had been developed in Georgia as an early-maturing cotton to escape the effects of caterpillars (Ware, 1951), probably cabbage loopers, *Trichoplusia ni* (Hübner). Although such things as the removal by hand of flared squares and weevils from cotton plants and the gathering of egg-infested squares beneath cotton plants became part of the Government Method (Mally, 1902; Hunter, 1904b; Newell, 1908; Knapp, 1911), planting early-maturing cultivars was the one component that growers could promptly accept since, obviously, these cottons did not disrupt normal farming operations; and because their benefits were so obvious — even to the most casual observer.

During the 86 years that intervened between the introduction of the Mexican Highland seed stocks by Burling and the first reported case of boll weevil infestation, the number of cultivars of cotton increased from two to 118. And between 1899 and 1904, the boll weevil caused an estimated reduction of 2,000,000 bales of cotton in Texas, a loss of $100,000,000 (Sanderson, 1905). When one considers the magnitude of the weevil problem during those times and the increase in apparently unique cultivars between 1806 and 1892, then the significance of Burling's trip to Mexico must be seen to rank with the development of the cotton gin by Eli Whitney. Perhaps cotton culture would not have survived without the unique genetic stock smuggled out of Mexico in 1806.

Because shorter-season cotton appeared to be the only practical way to survive the boll weevil, producers in Texas who had already experienced the destruction, and those east and north who realized that it was only a matter of time before the weevil migrated into their area, began to import in considerable quantities seeds of cultivars grown in the northern and northeastern ranges of the Cotton Belt. These cottons had been selected by necessity to be early maturing since they were grown in short-season environments. But the acceptance of these from northern areas to reduce losses to the boll weevil became a bittersweet remedy because of the cottons' poor fiber quality, a deficiency either not recognized or appreciated or honestly considered as these early-maturing cottons were brought into Texas with enthusiasm and some fanfare. There were some areas of Texas in 1892 that produced cotton of some renown, being listed as a standard on the Liverpool, England market: "Texas one and one-eighth." Typically though, the majority of the Texas cottons of 1892 had a shorter staple. The exact locales within the state are not identified, but Ware (1951) suggests that most of the cotton grown in Texas in 1892 averaged 15/16 to 1 1/32 inches in staple. And there was a strong market for these cottons. With the introduction of cultivars from the north, however, staple length shortened; and as early as 1904, Liverpool buyers had become skeptical about purchasing cotton on the San Antonio market because of the prevalence of 5/8 inch cotton; and whereas cotton buyers once readily accepted cotton produced from Bryan to Dallas, they soon began to be very selective in their purchases

(Helms, 1980). Hailed as a means to reduce losses to the Mexican boll weevil, these short-season cultivars ironically cost the Texas cotton producer markets, a turn adding to his economic plight. If the Texas grower was caught in this quality-quantity squeeze, then it surely affected producers in the Mississippi River Valley and further east who grew cottons such as Peelers, a type developed in 1864, and Allen, developed in 1879, cottons that enjoyed premium lint lengths of 1 1/2 inches (Ware, 1951). Spinners in the New England states were the primary buyers of these valuable long-staple upland types (Ware, 1951), and although the effects of the boll weevil on these cultivars can not be directly documented, it would seem that their production was halted completely in the early years of this century, presumably because of the boll weevil and the slow rate of maturity of these cottons.

In addition to deficiency in fiber quality, the imported northern cottons had other shortcomings. The Texas big-boll cotton cultivars that had been grown before the boll weevil exhibited a meaningful degree of "stormproofness" or the degree of lint retention in the carpel walls after boll opening — a feature lacking in the imported northern types. Much of the cotton producing area of Texas experienced winds sufficient to require some degree of protection against shattering. Too, producers in Texas and other parts of the southern portion of the Cotton Belt did not care for the small bolls of the introduced northern cultivars; small-bolled cottons slowed harvest. Although inferior fiber and small bolls and loose lint dogged the northern cottons, their superior yield performance under weevil attack became an object lesson demonstrating that there was resolution to the boll weevil — especially if cultivars could be bred for both the early quality and appropriate fiber length. Rather quickly, that would happen.

In the recognition of the need for a different kind of cotton for the southern parts of the Cotton Belt, procedures for the unbiased evaluation of the performances of available cotton cultivars became established. Newell and Rosenfeld (1909) reported on cultivar trials from 1906-1908. These tests were conducted in farmer fields across a range of soil types and native fertility. In 1906, Mebane Triumph, King, and "Southern Missouri" were compared with "native" seed at two sites in Louisiana; on the farm of D. J. Bland, "hill land," and on the farm of J. E. Byram, "alluvial Mississippi Valley soil." In 1908, near Marksville, Louisiana, Toole's Prolific, Mebane Triumph, native, and "Northern Oklahoma" were compared. The results of these and other evaluations enabled growers to make intelligent choices in selecting cultivars.

As farmers and seed dealers brought in large amounts of the seeds of the northern grown cultivars with the inferior fiber properties in their attempts to "outrun" the boll weevil, certain assumptions prevailed about early-maturing cottons:

1. The large-bolled cotton such as native Texas cottons could not be grown early enough to escape the weevil;
2. The northern types by their fast developing nature could not possess good staple ("staple cotton" was a common term for cotton which pulled 1 1/8 inches);
3. Early-maturing cultivars obtained from the north and northeast parts of the Cotton Belt would "adapt" to the longer season in the southern portion of the belt and thereby become late-maturing cotton.

However, R. L. Bennett (1904), who began cotton breeding investigations under the first United States Congressional appropriations for boll weevil work, realized the errancy of the above suppositions. After only one year, Bennett concluded:

1. Texas growers need not import early cotton to escape weevils;
2. Early cottons of superior quality could be obtained from native, big- boll, good staple, Texas cotton cultivars on any grower's farm. This could be accomplished by selecting plants with the desired characteristics.

Bennett noted from studies of many plants of all standard cultivars, and from studies of many nameless cottons, that the earliest-maturing plants "sent out the first fruit limbs at the joint nearest the seed leaf." Plants that fruit more rapidly than average, he found, had short internodes on the main stem and fruiting limbs. For productivity, Bennett urged producers to select the largest plants within the above guidelines. In the years since Bennett's observations, several scientists (McNamara *et al.*, 1940; Ray and Richmond, 1966; Smith, 1984) have quantified his observations. Many later reports on the nature of earliness in cotton have supported Bennett's view that faster-fruiting plants tend to have sympodia at lower main stem nodes, shorter square and boll maturation periods, and reduced vertical and horizontal fruiting intervals.

Leaving an impressive scientific record before entering the commercial cotton seed business, Bennett conducted experiments demonstrating that farmers could select for earliness or lateness, productivity or non-productivity, big leaves or small leaves, natural defoliation or leaf retention at maturity, for boll size ranging from 40 bolls per pound of seedcotton to 90 bolls per pound of seedcotton, as well as for stormproofness. Bennett (1908) secured seed of a common Texas cotton, name and history unknown, from Dr. J. H. Wilson of Quanah, Texas, and demonstrated the benefits of plant selection: Plants chosen in 1904 gave rise to progeny rows planted in 1905 yielding 1854 pounds of seedcotton per acre while the unselected parent yielded only 1630 pounds per acre.

In 1904, Dr. D. N. Shoemaker developed Express, an early cultivar not well accepted because it had small bolls and was not stormproof. However, it did have an improved staple length of 1 3/16 inches. Lone Star, released by D. A. Saunders of Smithville, Texas in 1905, was a big-boll, stormproof type with lint length of 1 1/8 inches (Brown, 1938a). These are but two examples of the rapid development of cultivars of cotton with sufficient early-maturity to be grown in boll weevil zones in the early 1900s, yet with satisfactory staple length. Both cottons supported Bennett's 1904 proposals.

So, earliness in cotton initially came by way of the short fiber "northern" types and later from cultivars specifically bred for earliness after the weevil's arrival. However, two cottons with sufficient earliness to escape weevil damage had already been developed before the hour of the boll weevil, and these were being planted in Texas. Though both had adequate fiber length, these cottons seem to have been overlooked in the first confused years of the weevil's tenure. Perhaps the most widely grown was Triumph, a cotton selected by A. D. Mebane of Lockhart, Texas, using the plant to row method. An unusual man, a man venerated in later years by cotton interests, Mr. Mebane was both farmer and plant breeder (but without portfolio). Mebane Triumph became a kind of standard by which to judge new cultivars grown under boll weevil infestation, and the cotton was widely planted for many years (Ware, 1951). It seems then that, had there been interest, many cultivars with earliness and quality fiber could have been developed before the weevil's entry. But in the absence of the pest, it is evident breeders of the southern parts of the Cotton Belt attached little value to earliness.

Cotton breeding had been practiced in the United States through selection of seed and plant characteristics from 1807 until the early twentieth century. Some hybridizations were made along the way but scientific cotton breeding began with Dr. H. J. Webber, a USDA scientist hired in 1898 to develop improved cultivars of upland cotton. Although some cotton breeding had already taken place at several state experiment stations, including Alabama, Georgia, South Carolina and Tennessee, the programs had been of little permanent value (Brown, 1938b). By 1914 a new force was beginning to exert influence on the United States cotton farming scene. Men of vision realized the commercial application of the new-found science of plant breeding. Initial hybridizations and selections for commercial sale of cultivars had begun at Hartsville, South Carolina by D. R. Coker, and at Stoneville, Mississippi by H. B. Brown and E. C. Ewing (Ware, 1951) — the days when each farmer selected and saved planting seed were coming to an end. The commercial cotton breeder, armed by the new and rapidly expanding knowledge of genetics, supported by germplasm enhancement by USDA and experiment station breeders and geneticists, would work a modern miracle, albeit slow, over the next 50 plus years.

DATE OF PLANTING

With the coming of the weevil, the term "earliness" took on a much different meaning. Prior to the 1890s and early 1900s, a cultivar or crop was early if it matured a reasonable number of bolls prior to frost. But during the early weevil years, farmers and agricultural scientists began to think of an early cultivar and early production in terms of the production that occurred before the late season buildup of boll weevil populations. Early planting as well as fast maturing cottons was recommended to achieve this goal. The entreaty (Howard, 1896; Mally, 1902; Bennett, 1904; Brown, 1938c) to plant as early as possible in order to make an early crop probably told farmers what they already knew. Producers would have seen from experience that early planting resulted in an early crop and less weevil damage or would have learned the same thing from word-of-mouth advice of other farmers.

Although the apparent way to live with the boll weevil was through early-maturing cultivars, early planting and cultural practices to promote earliness (Howard, 1896; Mally, 1902; Knapp, 1911; and Newell and Rosenfeld, 1909), the idea of late planting as a tactic to starve the emerging overwintering weevils in the spring periodically surfaced. The rationale of late planting was that it delayed the appearance of the first cotton squares so that food was denied to weevils recently emerged from winter quarters. As sound as that may have appeared, it rarely, if ever, worked. Having built to great numbers on early-planted cotton, weevils would disperse and flock to late-planted cotton, overwhelming it before an adequate crop could be made. Newell and Rosenfeld (1909) dryly made the following succinct comments about late planting:

1. Weevils emerge in Louisiana from March 22 through June 28. Over 30 percent of the weevils remain in winter quarters until May 15;
2. Cotton planted early is squaring rapidly by July 1 when weevils are reproducing rapidly and it therefore has a chance of producing squares faster than the weevils can destroy them;
3. Cotton planted late is squaring very slowly by July 1 while weevils are reproducing very rapidly; and,
4. If late planting was useful then surely some of the "thousands" of Texas farmers would have discovered that fact by accident by 1908.

Later in this chapter we will describe how purposefully delayed planting in a region of Texas has reduced weevil losses.

ROW WIDTH AND DRILL SPACING

While it is true that the search to find ways to live with the boll weevil stimulated interest and spurred investigations into optimum row widths and plant densities for earliness, these types of scientific inquiry were underway before the weevil affected production and, in some instances, before the boll weevil was ever heard of. The earliest report was by the North Carolina Agricultural Experiment Station in 1888 (Reynolds, 1926). Similar studies were reported from South Carolina, Georgia, Alabama, Mississippi, Louisiana, and Texas before 1907, with many of these conducted obviously before the impact of the boll weevil had been felt (Barrow, 1894; Duggar, 1897, 1898, 1899a; Ferris, 1904; Fox, 1907; Lee, 1889, 1891, 1892, 1893, 1894; McBryde, 1891; Newman, 1890; Newman and Clayton, 1891a, 1891b; Pittuck, 1897; Pittuck and McHenry, 1899; Redding and Kimbrough, 1906; Newell, 1909b).

Typical conclusions were those of Redding and Kimbrough (1906): "The experiments that have been made indicate unmistakably that the cotton plants should be thinned to one in a place; and that the rows should be narrow and the plants wider so as to be more nearly equidistant. Of course on very thin land requiring a very thick stand, the rows can not be economically, with reference to expense of planting and cultivating, closer than 30-36 inches and plants may then be not farther apart than 10 to 12 inches...land capable of a yield of 3/4 to 1 1/2 bales per acre the rows should be 3 1/2 to 4 feet wide and the plants 12 to 18 inches apart in the drills, the narrower rows and the closer spacing for less productive soils." However, Newell (1909b) reported on plant spacing studies conducted in Louisiana in 1907 and 1908, comparing wide (rows 6 to 7 feet apart and plants 18 to 24 inches apart), medium (rows 4 1/2 feet apart and plants spaced 12 to 15 inches), and narrow (rows 3 to 3 1/2 feet apart with plants spaced 12 inches within drills) rows. Of four such experiments, the narrow rows outyielded both wide and medium row widths.

Brown (1923) concluded from 64 spacing experiments conducted across the Southeast and Mid-South that the superior and most consistent yields, in the absence or near absence of the weevil, were from plants spaced 12 inches apart in 3 1/2 to 4-foot wide rows. On less fertile land, closer spacing gave better yields. Under slight to heavy weevil infestation, Brown concluded that it was not practical to leave plants close enough in the drill for maximum yields. Grass and weeds had to be removed with hoes that measured 7 to 8 inches wide, and therefore the producer, at best, could obtain only two to three plants per hill spaced approximately 12 inches, since a chopper rarely "came within an inch of what she was looking at," and sometimes, "was not looking at the row at all." Brown suggested that producers try to obtain four plants per hill on poorer soils. Brown noted that, "with heavy weevil infestation the fruit must be set in a very short period of time, say a month or less." This time period, thirty days or less, is similar to that proposed by Walker and Niles (1971) for the short-season production system that has found favor with producers in parts of Texas, as we shall cover in a later section.

For a brief period following the weevil's entrance from Mexico, the strategy was to plant very wide rows since immature weevils in fallen squares often perished from hot, dry weather when squares fell into clean, dust-mulched middles where abundant sunshine could reach (Mally, 1902). In fields with rank stalks, such as that found in the fertile alluvial soils of river bottoms, little sunshine reached fallen squares and survival was much favored. Mally advised growers to plant in wide rows, cultivate often to create a dust mulch and cultivate in such a manner as to create a slope towards the middle of the furrow such that shed squares would be blown by spring winds toward the open and sunny middle. In addition, growers should plant rows in a direction that allowed the greatest penetration of sunlight; plant such that prevailing winds would blow the fallen squares into the cultivated furrow and away from the natural shade of the plants. Mally's wide rows did not endure, and in time standard row widths of about 36-40 inches came to be accepted.

Soon scientists recognized that closer spaced rows or closer within-drill spacing of plants suppressed the development of vegetative limbs and hastened maturity, encouraging the development of more uniformly small plants (Cook, 1913; Martin *et al.*, 1923). Reducing plant size was desirable under boll weevil conditions, for it created a microclimate conducive to weevil mortality, the same reasons expounded by Mally in defense of wider rows. Hunter and Pierce (1912) reported 23.8 percent mortality of immature weevils from heat and dryness in cotton middles where sunlight could penetrate. Smith (1921) reported up to 91.3 percent mortality under Florida conditions, and McNamara (1927) suggested that it could be even higher in the dryer areas of Texas.

By the 1930s, it was well established that where the boll weevil was a recurring pest, a population of 50,000 plants per acre would result in higher yields and earlier maturity than would result from a stand of 10,000 plants, which was often recommended in non-weevil areas (Reynolds, 1926; Ware, 1930; Cotton and Brown, 1934). It was recognized that thicker stands resulted in fewer blooms per plant but more blooms per acre during the early blooming period; and that translated into a yield increase in the first harvest, although not necessarily in an increase in total yield. But the increase in earliness was often the major objective in combating the weevil; in later years, the pink bollworm, bollworm, and tobacco budworm. Common to all spacing and planting density work from 1888 to the present has been the goal to discover the optimum row configuration and plant density that will result in highest cotton yields.

Although production technology and cultivars have changed dramatically since the introduction of the boll weevil, the desirability of developing earlier-maturing cultivars and technologies to achieve earlier crop maturity remains. Vital to early maturity in modern production is the control of certain insects that delay crop maturity: *Lygus* spp., thrips and cotton fleahoppers; and establishing earliness by eliminating their damage often translates to reduced problems with weevils, bollworms, and tobacco budworms. In recent years, earlier-maturing cultivar development, the Texas short-season production technology and very narrow-row/high plant population production technology have received much attention relative to earlier crop maturity (Davis *et al.*, 1978; Niles, 1970; Taylor, 1971; Ray, 1970; Walhood and Yamada, 1972; Bridge *et al.*, 1975; Bridge, 1986; Sappenfield, 1985; Bird *et al.*, 1986; Smith, 1988).

FERTILITY

A considerable amount of on-farm experience had occurred by 1912 with organic and inorganic fertilizers, along with some scientific experimentation that documented the amount of nutrients removed from the soil by cotton (White, 1896; McBryde, 1891; Duggar, 1899b). But, as with the development of early-maturing cultivars and recommendations on row widths and plant densities, the boll weevil was the new impetus to investigations into the nutrition of cotton (Newell and Rosenfeld, 1909; Hunter and Coad, 1923). Bennett (1904) noted that nitrogen had been known for some time to hasten growth but also to delay the onset of fruiting; that potash would delay maturity; and that phosphorus would hasten fruiting and early boll set. Later, of course, it was recognized that proper nutrient balance only brought optimum growing conditions and that the apparent delay or improvement in earliness were only artifacts. The following are data of Bennett (1904) from experiments conducted in 1903:

Fertility treatments	Plant height	Squares/stalk @ 65 days	First harvest	Total yield
Acid P	18	8-16	683	1003
N	6-9	0-4	195	570
K	6-9	0-4	320	684
O	6-9	0-4	343	740
Complete	—	—	720	1105

- Plant height in inches; harvest in pounds seedcotton per acre -

Such results led early scientists to conclude that phosphorus, in some way, caused cotton plants to fruit faster and yield more in the presence of the boll weevil, again an artifact. The obvious benefits of adding nutrients to soils were seen in crop earliness and yields and were especially striking on the southeastern soils that had been cropped for many years with little attempt made to replace depleted nutrients or to provide nonexistent nutrients.

Scientists would soon determine the role of phosphorus in the energy system of plants, learning that it is stored in relatively large supply in seeds for the energy process. But in 1903 too little phosphorus meant poor plant health, fewer seeds and thus less fiber. By 1923, and in the years since, agricultural scientists were urging producers not to use excessive fertilizer, especially nitrogen, because the abundant vegetation that followed caused problems of late maturity and hindered insect control (Hunter and Coad, 1923; Brown, 1938d; Nelson and Ware, 1932; Murphy and Sanborn, 1929; Tucker and Tucker, 1968; Mistric, 1968; Beckham, 1970; Maples and Keogh, 1971).

CHEMICALS THAT HASTEN MATURITY; IRRIGATION AND NITROGEN MANAGEMENT

In more recent times, scientists (Kittock *et al.*, 1973; Bariola *et al.*, 1976; 1986; Bariola and Henneberry, 1987; Ehlig *et al.*, 1983; Hopkins and Moore, 1980; Kittock *et al.*, 1979) explored the possibilities of reducing the number of days required to produce and harvest cotton by terminating the growth of the crop by certain chemicals. This line of work showed that use of ethylene producing compounds late in the season will cause squares and small bolls to shed, thereby eliminating food supply and reducing the population of diapausing pink bollworms and boll weevils.

In the desert areas of New Mexico, Arizona, and California, where rainfall rarely interferes with irrigation scheduling, producers can reduce or eliminate late irrigations and decrease nitrogen fertilization such that the crop will "cut-out" earlier (Kerby *et al.*, 1984). This production strategy allows for earlier stalk destruction and reduces populations of diapausing pink bollworms and boll weevils.

REDISCOVERING EARLINESS

The groundswell for earlier-maturing cultivars diminished by the 1920s as the "Promised Land" of complete chemical control of insects arrived in the form of an insecticide, calcium arsenate, a product that growers never enthusiastically accepted. If breeding for earliness lost momentum with the appearance of this chemical in 1916 (Coad, 1918), then it came to an almost complete stop with the development of the organic insecticides after World War II. These later compounds were far superior to the arsenical, and the need for earliness as an escape mechanism was no longer so persuasive. This hiatus of sorts, especially after World War II, away from the major push to develop earlier genotypes, gave the fledgling cultivar development industry an opportunity to concentrate on yield potential. Breeding efforts in the rainbelt and irrigated West were directed almost entirely to yield potential of full season types, to take advantage of the botanical indeterminacy of cotton. Yields have steadily increased in the Mid-South, averaging 21 pounds (9.46 kg) of seedcotton gain per acre per year from 1910 to 1979 (Bridge and Meredith, 1983). Surely similar results could be claimed for the remainder of the United States Cotton Belt.

Calcium arsenate had provided a means of significantly reducing losses to the boll weevil, but its use was often linked with outbreaks of secondary pests (Ballou, 1919;

Sherman, 1930). However, the shortcomings of this chemical were forgotten with the synthetic chlorinated hydrocarbon insecticides, and the exodus away from early-maturing cultivars became complete (Walker, 1984). However, by the mid-1950s, the constant selection pressure on the boll weevil population effected a shift in the creature's gene pool to one that contained a large percentage of individuals resistant to the chlorinated hydrocarbons (Brazzel, 1961; Roussel and Clower, 1955). The agricultural chemical industry responded with the organophosphate methyl parathion; and it gave almost complete control of weevils; and chlorinated hydrocarbons, such as DDT, were added to control bollworm and tobacco budworm. The American cotton producer was mesmerized, for the moment, into thinking that all insect problems could be corrected with the right chemical(s). However, within a few years increased dosages of the chlorinated hydrocarbon compounds were often required to control bollworm and tobacco budworm; and by 1965 these chemicals were deemed ineffective in certain areas of the Cotton Belt (Adkisson, 1964; Adkisson and Nemec, 1966; Brazzel, 1964; Harris *et al.*, 1972; Nemec and Adkisson, 1969). For a brief period, bollworm and tobacco budworm were controlled with high rates of methyl parathion; but resistance was soon detected in the tobacco budworm (Brazzel, 1963). With this development, researchers began turning their attention toward the advice of Mally and Bennett sixty years before. New interest in developing earlier-maturing cultivars began in the 1950s, accelerating in the '60s and '70s. Producers and entomologists began to look again for earlier maturity as the cornerstone of cotton insect management. Shortening the growing season reduced exposure time to insects, thereby reducing the number of insecticide applications. Less insecticide was lauded by all, for it placed less selection pressure on insect populations, was cheaper and environmentally desirable. Where bollworm and tobacco budworm outbreaks were attendant with late season insecticide applications for control of weevils, earliness became the structure around which schemes were designed to manage the boll weevil, schemes with less dependence on insecticides. With the rediscovery of earliness and cultural control in general, equipped now with new knowledge of the biology of weevils and other pests, integrated pest management (IPM), systems approach, short-season concept, and communitywide approach became the slogans of the day; and early-maturing, more agronomically determinate cultivars were once again the cornerstone. Walker and Niles (1971), working to understand economic thresholds of the weevil, found that fast-fruiting genotypes could set an acceptable crop of bolls that could escape first generation weevil damage if fields were infested with twenty or fewer overwintered females per acre. But if 60 or more females were found, then the first generation population of weevils would be of sufficient numbers to cause economic loss. This work led to the conclusion that it was important to have thirty days of blooming before weevils built to damaging levels. Thirty days of blooming would result in a sufficient number of bolls, of sufficient age, to escape major damage (Walker and Niles, 1971). Therefore, genotypes setting the greatest number of bolls in the first thirty days of blooming would have a production advantage under reduced insecticide production schemes.

This understanding of overwintering weevils and population dynamics was refined by Parker *et al.* (1980) who reported that 5000 or more punctured squares per acre before bloom meant that a destructive population would build by the twentieth day of bloom, while 1500 or fewer punctures indicated that damaging levels would not occur until the thirtieth day of blooming, or later.

From 1970 through 1973, Sterling and Haney (1973) directed the systems approach to insect management on the farms of the Texas Department of Corrections, increasing yields and decreasing insecticide use. Other researchers reported on the economic advantage of integrated pest management (Carruth and Moore, 1973; Frisbie *et al.*, 1976; Larson *et al.*, 1975; Collins, *et al.*, 1979).

Another event has recently sparked interest in short-season cultivars. The energy crises of the 1970s and the resulting inflation hammered home a startling point: Chemicals were no longer cheap and irrigation water would become more expensive (Schaunak *et al.*, 1982); and in this new reality, short-season cultivars broadened their appeal.

We now digress to the mid-1950s to document one of the first renewed efforts to move toward earlier-maturing cultivars for rainbelt production. Carl Moosberg, USDA cotton breeder headquartered at Marianna, Arkansas released, in 1957, the cultivar Rex; and it was a cotton meaningfully faster fruiting than the then currently available cultivars (Waddle, 1957). Developed for mechanical picking and rainbelt production, Rex was 10 to 14 days earlier than other commercially available cultivars in Arkansas; and in one comparison at Marianna, Rex produced 1112 pounds of seedcotton at first harvest while a "popular cultivar" produced only 409 pounds. Rex outyielded the check cultivar by approximately 350 pounds of seedcotton (Moosberg and Waddle, 1958). With the development of Rex, Moosberg, as had Bennett (1904), demonstrated that earliness could be obtained without sacrifice of yield or quality in picker-type cottons. Ironically, Rex's phenotype was similar to that advocated by Bennett (1904); it had short sympodial internodes and, for 1957, much shortened vertical and horizontal fruiting intervals.

With the cumulative problems of resistance in populations of weevils and tobacco budworms; with harvest problems of late-maturing cultivars, especially in years when the effective growing season was reduced by the early onset of low temperatures; with harvest problems that arose with excessive rates of fertilizer, especially nitrogen; and with the possible delays in maturity associated with certain organophosphate insecticides, breeders began to follow Moosberg's lead, giving consideration to earlier-maturing genotypes. The move to earlier-maturing picker types gathered steam with the release of the DES cultivars in Mississippi in the early 1970s, quickly to be followed by privately developed early-maturing cultivars; and today all cultivars grown in the Mid-South are considered early-maturing. In fact, Bridge and McDonald (1987) found that 34 fewer days were required from planting to final harvest of the Mississippi Cotton Cultivar Trials at Sumner and Stoneville in 1986 than were required in 1968.

As breeders in the Southeast, Mid-South, and Far West proceeded cautiously toward short-season cultivars, attempting at the same time to maintain agronomic indeterminacy, breeders in Texas moved quickly to determinate, ultra short-season (for their day) cultivars. The work of Walker and Niles (1971) had demonstrated the wisdom of planting these types, and L. S. Bird and others put the concepts into practice. Tamcot SP21, SP23, and SP37 were released in 1973; and they fit the requirements for determinacy and productivity (Adkisson, *et al.*, 1982; Bird, 1975). These cultivars were especially useful for production in the Coastal Bend area of Texas. The expense and difficulty of insect control had almost driven cotton production out of this five county area near Corpus Christi, with only 50,000 acres remaining by the early 1970s. Acreage planted to cotton in this region increased dramatically during the years following the release of the determinate Tamcot germplasm, and by 1979 near 300,000 acres were grown. Adoption of the Tamcot cultivars and the attendant cultural control of the boll weevil through early harvest and stalk destruction have resulted in an estimated increase of $11,000,000 in producer profits in 1979 (Lacewell and Taylor, 1980; Masud *et al.*, 1980).

In higher rainfall production areas, short-season technology, as that used in the Coastal Bend of Texas, could not be transferred. Normal rain patterns and amounts, less than 40 inches, supported the use of determinate types in the drier Coastal Bend area of Texas. But in areas that receive 50 inches of rain per year or more, the new determinate Texas cultivars were found to be poorly adapted. Rainfall amounts and distribution in those areas dictate a less determinate and larger plant type for optimum economic yields. In the irrigated areas of New Mexico, Arizona, and California, agronomically determinate types are presently not acceptable because of the availability of irrigation water and an accommodating long production season that encourage the use of agronomically indeterminate cultivars for maximum yields of superior quality lint. However, all producers in the United States recognize the value of earlier cotton production; they recognize the dollar savings associated with the reduced inputs and are more comfortable with the lower risks that earliness carries.

SEEKING PLANTING LOCATIONS OF LESS RISK

Among the cultural recommendations to emerge from entomological research in Texas in the first years of boll weevil infestation was the cautious suggestion that cotton might be planted at locations where there was less risk from the pest; by 1912 some growers had found the merit of the advice. Hunter and Pierce (1912) showed with maps the decreasing intensity of weevil attack in Texas as cotton had moved west, especially where the crop was planted west of Austin. They added that the percentage of Texas bales produced in this area was increasing yearly. By the late 1920s, near five million acres of cotton were being planted in the Rolling and High Plains as dryland cotton (Bonnen and Gabbard, 1947); and this was acreage free from the weevil. The lower rainfall here, 18 to 25 inches, the low humidity and the harsh winters, all seemed to wall off this space of the state from the weevil; and the classical maps published each year by the USDA that charted the weevil's advance in the United States dramatized how western Texas formed as a redoubt, country free from the insect (Metcalf and Flint, 1939).

The High Plains had little of the forest habitat so important to overwintering of the weevil in the east; and if patches of hardwood cover could be found in the Rolling Plains, the pest had great difficulty in establishing in threatening numbers. If the weevil overwintered here in those years preceding the late 1950s, it was only in seasons of extraordinary description; and even then it was in scatterings of meager numbers. These lines held until the 1960s. Then boll weevils, likely through the genetic selection of a biotype, began to overwinter, and in large numbers, in the Rolling Plains. A recent cultural strategy for this new turn will follow in the next section.

The appeal of growing cotton where boll weevils were presumed absent was persuasive; and that, together with irrigation technology, prompted the crop movement west, to California, Arizona and New Mexico (Turner, 1981). Grown fitfully in California, experimentally and commercially, before and after the Civil War, cotton by the late years of the nineteenth century had been abandoned in the state. Then, in attendance with the development of western irrigation projects after the turn of the century, cotton acreage started back and grew to include production in Arizona and New Mexico.

The series, CENSUS OF AGRICULTURE, published by the United States Department of Commerce, provides the following data on the extraordinary growth of western production:

State	Year	Acres of cotton
California	1889	0
Arizona	1889	0
New Mexico	1889	0
California	1909	324
Arizona	1909	19
New Mexico	1909	790
California	1919	87,308
Arizona	1919	106,283
New Mexico	1919	10,666
California	1929	300,058
Arizona	1929	211,178
New Mexico	1929	136,700

For the moment, this new production in the western states, for all purposes, had left the boll weevil behind; but, as we wrote, another insect, the pink bollworm, would soon take its place. Adding to that problem has been the recent elevation of the pest status of the boll weevil in Arizona (Moore, 1985). But for years the western strategy had worked; and even today the largest production area, the San Joaquin Valley, remains free of the weevil and the pink bollworm. [In 1912, a form of the boll weevil was unexpectedly recorded in Arizona on a wild mallow, the thurberia plant (Pierce, 1913); and a few years later the insect was noted as a pest of Arizona cotton. But infestations for years were sporadic and commonly of little consequence, though severe damage was measured occasionally. For a number of years, the biology of this Arizona insect seems to have been different enough from the biology of the boll weevil of eastern cotton that the Arizona weevil was less a threat to cultivated cotton. That status gradually changed, and today the boll weevil of Arizona cotton possesses the same imperious qualities that characterized the highly destructive boll weevil of southern Texas in 1894.]

If cotton could be grown almost free from the weevil for a long period in the arid western states, it also could escape much of the damage of the pest by moving north in rainbelt country. The crop of northern Arkansas no doubt benefitted; but the "northern tactic" is probably better illustrated by acreage growth in Missouri, especially in the Bootheel of this state (Lewis and Richmond, 1968). The CENSUS OF AGRICULTURE gives these data:

Year	Acres of cotton, Missouri
1899	57,260
1909	96,527
1919	110,027
1929	352,899

Cold winters, perhaps a paucity of overwintering habitat, contributed to a reduced weevil problem; and growers took advantage of it.

In short, about six million acres of cotton were being grown in the late '20s in country chosen in part because it was recognized that the boll weevil either was not a threat or, at worst, only a small matter for concern. Growers had exercised an option to plant acreage at locations purposefully selected to avoid the insect, a cultural option.

Within the traditional country of rainbelt cotton production, growers probably selected certain planting sites because they regarded the weevil as less a threat there. Certainly, any field distant from extensive spaces of trees and leaf litter where the insect could overwinter in great numbers owned an advantage; and Rummel and Adkisson (1970) described, in some detail, the likelihood of weevil infestations in cotton fields located at various distances from wooded habitat in the Texas Rolling Plains. Again, exercising a cultural option, growers here could select planting fields based on the calculations of risk presented in that study.

COMMUNITYWIDE DELAYED PLANTING

Time and time again, entomological writers of the first twenty years of this century, as they considered the course of action to be taken against the boll weevil, entreated farmers to plant cotton early. The Government Method considered early planting as a major tenet, ranking in importance, probably, just beneath the selection of a cotton variety that produced quickly. For most of the cotton of the United States, early planting still forms as a requisite for a judicious cotton farming operation. There is, however, an exception.

Secure from damaging infestations of the weevil until the early 1960s, the Rolling Plains of Texas, a region of low inputs, frugal budgeting and low yields, could not add the extra expense of a series of insecticidal treatments for weevil control to its tightly defined economic situation and survive as a viable cotton producing region. Because Rolling Plains cotton is not harvested until November or later, early stalk destruction could not be used as it is in south Texas to manage weevils. An alternative was needed and one was developed. Out of indepth ecological investigations of weevils in the Rolling Plains came understandings, and these led to a major cultural adjustment by cotton growers. Investigating the overwintering weevil habitat and cotton of the Rolling Plains, Rummel and Adkisson (1970) remarked the obvious effect of phenological age of cotton and the disposition to weevil attack. Intensity of infestation was clearly more severe in early planted fields, and these entomologists conjectured that cotton purposefully planted late might serve as a management strategy. In controlled studies in the region, Slosser (1978) verified this.

White and Rummel (1978) added understandings of overwintered weevil infestation, describing the pattern of entry into early-planted and late-planted cotton. Far more weevils entered cotton of both planting times after the first squares appeared — though sharply fewer infested the late-planted. Other Rolling Plains' studies examined the longevity of overwintered weevils infesting cotton at different phenological ages of cotton; in the absence of fruit, mortality came swiftly. On the other hand where squares were present, 67 percent of the individuals lived more than twenty days (Rummel and Carol, 1985). Early emergence and establishment in cotton before squaring, then, carries high mortality risks.

Studying the population dynamics of the weevil in Rolling Plains cotton, Slosser *et al.* (1989) measured the build-up of the first generation from eggs oviposited by overwintered weevils. Expressing essentially no growth, first generation numbers were contained by the typically harsh, dry environment and represented no threat to yields of cotton of the study. The rate of the drying process in larval infested squares has been shown to be critical to survival to the adult stage (Curry *et al.*, 1982); should the process hasten, as it clearly does in dry environments, it hazards the life of the developing weevils. That is, as heat increases with the progression of summer; and when humidities are low, the risk of death of immature weevils in infested squares heightens. Delayed squaring in cotton can represent danger to immature boll weevils in the Rolling Plains.

These several findings were the substance and logic for areawide, delayed planting of cotton, a practice that delays square production until late June-early July. Taking advantage of a high level of suicidal emergence of overwintered weevils that occurs when there is an absence of squares, the system also enjoys the benefits that accrue from pushing the early squaring period later into the summer, to a time of hotter weather when square drying is more critical for immature stages. This program has been adopted by Rolling Plains growers because it works, and because it fits the requirements of the budgets of the low input Rolling Plains production. It costs nothing to delay planting. Economic analysis has measured the benefits of the practice (Masud *et al.*, 1984). Planting dates, varying of course from north to south in the Rolling Plains, are set for the different communities. The program encourages growers within a community to complete planting in as short a period as possible so that square production in all cotton initiates about the same time, a result that tends to even overwintered boll weevil numbers among cotton fields. Recommended planting dates are about two weeks later than those previously used.

HABITAT MODIFICATION OR REMOVAL

The possibility of direct action against woodland habitat known to harbor diapausing boll weevils has long piqued the interests of cotton entomologists. Hunter (1909a) wrote of procedures to counter survival of the pest during the winter, and Isely (1930) described how 600 acres of cotton fields were freed of the immediate risk of infestation by clearing brush and undergrowth from about 50 acres of land interspersed among the 600. As an ongoing process, the clearing of large tracts of land to row crop cotton and other crops certainly has brought the same benefits noted by Isely.

Recently, the possibilities of addressing overwintering of the insect in localized, man-constructed habitats — habitats that grew out of the experience of Dust Bowl times — have been examined. During the period 1936-1942, the Prairie States Forestry Program planted belts of several species of trees in sections of the Rolling Plains. Called "shelterbelts," often 100 feet in width, these strips interposed the cropland, serving to reduce wind-caused soil erosion. In time, the accumulation of leaf litter began to satisfy the requirements of overwintering weevils. By the 1960s, weevils were spreading to these opportunities for overwintering; and where the belts were located near cotton they became a source for weevil establishment. Slosser and Boring (1980), on this account, initiated studies on certain cultural practices for management of overwintered weevils in the shelterbelts. Describing the reduction in weevils recorded in leaf litter following fire, these entomologists concluded that the fewer numbers did not justify the damage to trees; and, moreover, secondary sprouting followed, with fresh litter swiftly accumulating. With another approach, they measured the positive benefits of pruning certain species of trees in the strips: Pruning brought highly variable temperatures to the leaf litter, and Slosser and Boring regarded this as responsible for the greater winter mortalities of weevils recorded. Writing to the future, they advise caution for expanded shelterbelt programs, recommending the selection of only those trees whose leaf litter is known to be inferior as weevil overwintering material (Bottrell *et al.* 1972). For regions free from the boll weevil because of a lack of overwintering habitat, the High Plains of Texas for example, that would consider the planting of shelterbelts, Slosser and Boring advise careful scrutiny and planning of the activity. Apparently the wide shelterbelts of the Rolling Plains, which accumulated substantial areas of litter, are not needed to stop wind erosion. Narrow belts of one to three rows of trees would fulfill the need. Nevertheless, it seems to us that the introduction of a network of windbreak belts to the millions of acres of the Texas High Plains would transform a habitat largely barren of weevil overwintering quarters to one that would permit winter survival. The scale of that survival would become known only after the fact.

IRRIGATION TIMING

Slosser (1980) explored the effects of irrigation on bollworm infestations in cotton of the Texas Rolling Plains in experimentation of three years. Using the computer forecasting model, MOTHZV-2 (Hartstack *et al.*, 1976), he was able to predict (and anticipate) peak periods of oviposition (egg laying) in cotton, verifying these by sampling.

The model proving accurate, Slosser showed that irrigation applied during peak moth activity abetted the pest in two ways: (a) In cotton that was water-stressed at the time of irrigation, more eggs were deposited than in water-stressed cotton not irrigated; (b) and, in cotton not suffering from water stress, irrigation applied at peak ovipositional activity smartly increased larval survival over the non-stressed, non-irrigated control plots.

Because the computer model established accurately, within a few days, the time of peak oviposition, Slosser concluded that the predictions could be used, by design, to advance or delay an application of water purposefully to the detriment of the bollworm.

PLANT BUG MANAGEMENT IN ALFALFA AND COTTON

Cotton culture of the San Joaquin Valley of California enjoys an enviable status among the production regions of the United States: Neither the pink bollworm nor the boll weevil occurs here, and consequently insecticide and miticide use is insignificant. Secondary attacks, bollworms and tobacco budworms for example, that so commonly break out in other regions following treatments for the weevil or pink bollworm are not a factor in the Valley today. But this has not always been the case. University of California entomologists remember a period thirty years ago when insecticide use for the plant bug complex, principally *Lygus hesperus* Knight, was followed by multi-treatments for a complex of other pests; sometimes as many as eight were required (personal communication, V. M. Stern). Research began to explore this problem. Alfalfa, investigators noted, served as one of the main reservoirs of the bugs, and the cultural management of alfalfa had much to do with infestations of these pests in cotton (Stern *et al.* 1964; Stern *et al.* 1969). Preferring lush alfalfa, plant bugs primarily would remain in strips of the hay crop interplanted in cotton if these strips were maintained lush by irrigation. When marked bugs were released, most found their way to the alfalfa, not cotton. The hay obviously was a superior host for the bugs.

Harvesting practice of alfalfa was directly incriminated as influencing the spread of the bugs to cotton. If complete harvest of an alfalfa field caused massive migration of plant bugs to cotton, entomologists found that cutting the hay in strips and leaving strips of uncut hay held the bugs in the uncut strips. Again, it was necessary to maintain the alfalfa in a lush condition. Growing from this has been a conceptual understanding of California growers: that it is their management of alfalfa that determines whether plant bugs become a pest of nearby cotton. Providing clarity to a once perplexing cotton problem, research has guided farmers into alfalfa production schemes that influence the course of plant bug infestation in cotton.

OTHER CULTURAL APPROACHES

The possibilities of small plantings of cotton, trap crops, as a piece of the overall boll weevil strategy have occupied the interests of entomologists since the days of Townsend. A leitmotif (leading motive), this approach through the years has waxed and waned only to flourish again as researchers were persuaded and discouraged before what appeared to be its transcending argument (Niles *et al.*, 1978). Transcending as it might seem, trap crop plantings have not found their way into practice. There are good reasons for this.

In its simplest form, the trap effect of early planted (and early fruited) cotton is its attraction to what are obviously disproportionately large numbers of overwintered weevils. This was surely noted by Texas farmers during the first seasons of the boll weevil, and it was formally recorded in the writings of Townsend and Mally. Extending from such observations was the recommendation of Mally (1902): plant, and at an earlier time, small plots of an early-fruiting cotton alongside fields that would be planted later to the main crop. The exaggerated numbers of overwintered weevils that gathered there were presumed to occur at the expense of the weevil infestation of the main crop: Overwintered weevils were being lured from the main and commercial planting by the early-fruited trap crops. Then as now, that was the appeal of this scheme.

Researched, trap crop planting seems to have lost a measure of practicality. It has been difficult to be able to sow the plots early enough in the season to fix a strong differential in fruiting between the plots and the main crop. And even when differentials in squaring rates have been effected, the reports of efficacy in managing the pest in the commercial cotton near the traps have been mixed (Niles *et al.*, 1978). Trap cropping for boll weevil management is not used today by farmers.

There are several once-recommended cultural practices that are largely forgotten today — from the use of a chain implement to drag fallen weevil infested squares to the middles of cotton rows, to the Florida Method (Little and Martin, 1942).

Evidently the Florida Method appealed to farmers of certain regions of the eastern United States and was practiced. Interesting because it seems to have been built on ecological understandings, the Florida Method entailed the removal, by hand, of the first squares punctured by overwintered weevils; these squares, and any weevils collected, were destroyed. Then, the cotton plants were either dusted with a single application of calcium arsenate or their terminals were mopped with syrup-calcium arsenate mixture. Based on weevil hibernation cage data that suggested that major colonization of overwintered weevils had occurred by the time of first squares, this approach was used by Florida growers farming the crop on lower yielding soils (Little and Martin, 1942; Smith, 1922, 1924). As an effective control, it seemed more appropriate for cotton grown in areas where weevil overwintering habitat was restricted. Although there is colonization of weevils after the first appearance of squares (Walker and Bottrell, 1970), more, certainly, than was likely indicated by Florida hibernation cage experimentation, the Florida Method evidently reduced oviposition by overwintered weevils sufficiently that it importantly decreased the size of the first summer generation (Walker and Niles, 1971). The modern strategy of boll weevil management by way of insecticide applications applied at first one third grown cotton squares is obviously an extension of the Florida Method of the 1920s.

LOOKING BEYOND

Elements of the cultural strategy formed in the ideas of cotton entomologists as they dealt with the turn of the century invasion of the boll weevil and, thirty years later, with the newly introduced pink bollworm. One tactic for the boll weevil, scientists argued, was an early-maturing crop. Row widths of about 40 inches, P and K fertilizers, early planting and early-maturing cultivars, they said, would bring earliness and reduce yield losses; and farmers bought almost immediately this program and saw the benefits. On the other hand, another tactic, that of prompt stalk destruction after harvest, though heralded far and wide, in print and harangue and oration, as the most meaningful practice available to growers, rarely was carried out in the early years of weevil infestation.

Much of the weevil strategy applied to the later infesting pink bollworm. Practices to secure earliness seem to have been accepted, and unlike the failed attempts to convince growers to cut stalks after harvest to control boll weevils, recommendations for stalk and field clean-up for the pink bollworm were followed. Cultural elements for the pink bollworm in those years to the 1950s showcased the cultural strategy. So, in one instance the cultural strategy seems to have been rather adequately used, in the other, only a piece of the approach was carried out. Through 1945 this was the way, this cultural approach, that two important cotton insects were managed in United States cotton; and it worked well enough that yields of cotton held up to historical comparison. In fact, starting in 1937 and in the years thereafter, but before the introduction of the synthetic organic insecticides, yields moved upward about 40 percent compared with the average yield of the ten years prior. As meager as it would seem today, production had advanced beyond 250 pounds of lint per acre as World War II concluded. The cultural strategy had demonstrated its value; the vitality of the cotton industry remained, despite the unbidden introductions of two injurious insects. Yet, few close to the crop imagined that yields might increase further without the addition of something more. There was to be something more.

The synthetic organic insecticides that appeared in those quick, enthusiastic and heroic years after World War II found their way into agriculture, and for cotton the benefits were astounding. Yields moved upward as insect and mite damage was powerfully reduced. A permanent shield from arthropod attack, safe and economical, seemed at hand; and the importance of the cultural aspect diminished in the eyes of the industry or at least was hardly thought of.

Earliness no longer received the attention it once had, and new cottons were bred for maximum yields, even if those cottons were slow in maturity. Nitrogen fertilizer, liberally used now to take advantage of the yield capability of the new cottons, further increased production. And if irrigation was available, it could be applied to lengthen the growing season and ensure even higher yields. Arizona growers, losing all fear of the pink bollworm and forgetting the years of cultural management, extended production late into the growing season. Effective insecticides used in multi-applications had brought this, and these products had few detractors. As one cultural practice dimmed, so another tactic, which had rarely been practiced with enthusiasm and timeliness in rainbelt cotton, was given wide currency. New tractor powered stalk-cutters were being used to destroy cotton stalks, though farmers saw this as less a practice for boll weevil management than a necessity for seed bed preparation for next year's crop. Nevertheless, for whatever reason, stalks began getting cut early enough to influence weevil overwintering. It was a first step. Such was the background and outlook in the early 1960s.

But changes were ahead. The recognition, for many reasons, of the value of earliness in cotton production and growing problems with resistance of pests to the new organic insecticides and, in the distance, a building clamor of environmental concern — all would clear the way for a production system less exposed to arthropod pests. Earliness was rediscovered, and much earlier-maturing cultivars were bred; fertilizer and irrigation practice was modified to capture the advantage of this earliness; and new maturity hastening chemicals reinforced the earliness goal. After Wilmon Newell demonstrated in the first decade of this century that more cotton was produced under boll weevil infestation with very narrow rows (36-42 inches), 38-40 inches row width became standard practice. But now, modern research showed that there was a maturity advantage of cotton grown in row widths less than 38 inches. Farmers began to try this rediscovery. The return to earliness and the adoption of stalk destruction for rainbelt cotton have led to superior insect management and have brought marked reductions in insecticides in some cases.

Perhaps all of this is not "coming full circle" but it does tell of the irregular course of the cultural strategy. The approach has operated in spurts and withdrawals with rediscoveries being made along the way as priorities have formed and reformed. Perhaps the meander of the cultural strategy through the years has obscured its value in modern cotton agriculture, but it is, nevertheless, a functioning part of pest management today. The goal for the future would be to make the strategy even more meaningful in managing cotton pests. Presently, much of the United States production hangs together only because there are effective insecticides to be used in multi-treatments. It is a fragile system.

The experience gleaned from over forty years of insecticide use on cotton has not been altogether comforting. Multi-application programs are expensive propositions, and the numerous treatments, no doubt, shorten the productive life of the chemicals themselves by promoting the development of insect resistance. Then another chemical is turned to — if one is available, and largely there has been one available. At some point before us, there might not be that available option.

Hence, it seems incumbent that the industry do those things that would further lower insecticide use on the crop. The cultural elements — earliness and prompt stalk destruction — seem to be the one realistic practice that could influence insecticide use in the immediacy. It seems foolish that we should wait until the efficacy of all insecticides has been exhausted by resistance before there is modification in the cropping system of cotton. And there is another compelling reason to reduce insecticide dependency.

The insecticides of the post World War II years and for a number of years following were given to farmers as tools to be used at their discretion, convenient products for agriculture in a laissez-faire setting. That is not entirely the case today; more, the prevailing political and social temper suggests that agricultural chemicals in general are to be increasingly examined, sometimes restricted. For example, it is not far afield to imagine that the total amounts of an insecticide permitted to be used on a crop, for a given season, may some day be set by law or edict. Such a prospect thirty years ago would have seemed unthinkable. Today it is but one of the several possibilities concerning insecticide use in agriculture.

Cotton then, often a high insecticide use crop, needs to move prudently toward a system less vulnerable to insects and mites, to a system where insecticides are a smaller component. Further shortening the production period and increasing earliness and vigorous, organized attention to stalk destruction would serve this end. Western desert production could accommodate these adjustments. And although such changes would seem more difficult for rainbelt cotton, we note the advances in earliness that have come about in the last twenty years in the new rainbelt cultivars, and we remember too that twenty five years ago there was, in some quarters, little support for developing such early-maturing cottons. But, in the end, it was done.

SUMMARY

The cultural approach for managing insect pests of cotton of the United States began in the years following the entrance of the boll weevil into south Texas in 1892. Recommendations of entomologists of the public institutions then contained two elements that are today as vital to judicious farming as they were in the first years of this century: crop earliness and prompt stalk destruction. Earliness has been achieved with a combination of practices: planting date, row width and planting density, fertilizer application and cultivar — but, perhaps it is the selection of the appropriate early-maturing genotype that has been most influential. The weevil problem of the early years was partially solved by planting faster-maturing cottons, and in recent times progress has continued in breeding plants that produce in a shorter period. Historically, genetic earliness for these cottons came from a distinct region in Mexico, the Mexican Highlands. Providing escape from large late-season infestations, fast cottons also allow the crop to be harvested earlier and the cotton stalks destroyed early enough to reduce overwintering in certain pests.

During the first years of boll weevil infestation, very wide row widths were recommended, but in time this concept was rejected; centers of about 40 inches are commonly used today, although experimentation in certain areas has shown that more rapid maturity can be achieved by planting on rows considerably narrower than 40 inches. On deficient soils, a balance of nitrogen, phosphorus and potash fertilizers has allowed early fruiting in cotton.

Destroying cotton stalks in the fall, a difficult task in the first years of the weevil, is now possible with modern machinery. Prior to stalk cutting, harvest practices (harvest-aid chemicals and mechanical harvest), have already reduced the overwintering numbers of certain insects. The winter survival of the pink bollworm is strongly influenced by tillage practices during the fall and winter, and by winter irrigation.

Required stalk cutting dates and plow downs have been promulgated in the laws of the states' Department of Agriculture for pink bollworm and boll weevil management.

Although early planting has stood for years as a tenet of insect management, recently the application, of delayed planting on a communitywide basis, has reduced weevil damage in the Texas Rolling Plains.

Farmers often in the past planted the crop where insect threat was less. The expansion of cotton to northwest Texas, to the Bootheel of Missouri, and to the western United States was prompted in part by the understanding that this was country free from major cotton insects or, at least, these were areas of diminished risk from insects. The wealth of that production still enjoys that advantage.

The timing of irrigation has been shown to influence infestations of bollworm in cotton of the Texas Rolling Plains, and other studies in this region have dealt with the management of overwintered boll weevils through the modification of the shelterbelts that are planted there to reduce wind erosion of soils.

Plant bug infestations in California cotton fields have been shown to relate to farming practice in nearby alfalfa, and modification of that practice can result in lower infestations in cotton.