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Controlling Cotton's Insect Pests: A New System

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Summary. Cotton is more heavily treated with insecticides than any other crop in the United States. In southern Texas, this heavy treatment resulted in insecticide-resistant strains of major pests which almost destroyed the industry in the late 1960's and early 1970's. An integrated insect control program based on new short-season cotton varieties and traditional cultural practices has restored production in the area. The new system has been widely implemented because it produces greater net returns by reducing the use of insecticides, fertilizer, and irrigation.

Almost 50 percent of all insecticides applied to crops in the United States are applied to cotton. As a result, most major pest insects of cotton have developed resistance to one or more of these insecticides. Some pests, such as the tobacco budworm [*Heliothis virescens* (Fabricius)] and spider mites (*Tetranychus* species) are now resistant to most of the insecticides registered for use on cotton in the United States. This is rapidly depleting the arsenal of effective insecticides for use on cotton.

An Insecticide-Induced Disaster

The decline in cotton production in northeastern Mexico and southern Texas in the late 1960's and early 1970's is an excellent example of what can happen when insect pests become so resistant to insecticides that control fails. In northeastern Mexico the area of land planted in cotton declined from more than 700,000 acres during the 1960's to less than 1000 acres in 1970 (*1*). Little cotton is grown in the region today. In the Texas Gulf Coast and lower Rio Grande Valley the area planted in cotton declined from 166,000 and 320,000 acres, respectively, in 1968 to 55,000 and 103,000 acres in 1975 (*2*). These reductions occurred because the tobacco budworm developed resistance to all registered insecticides. Although growers treated fields many times, the budworm inflicted such damage that cotton was not profitable to grow.

To understand how this situation developed, it is necessary to review the evolution of insecticide use on the crop in southern Texas, beginning in the 1930's. During this period the boll weevil (*Anthonomus grandis* Boheman), the pink bollworm [*Pectinophora gossypiella* (Saunders)], and the cotton fleahopper [*Pseudatomoscelis seriatus* (Reuters)] were the key pests of the crop. (A key pest occurs annually in a crop and must be controlled to achieve a profitable yield.) The boll weevil was controlled by calcium arsenate dust and the fleahopper by sulfur dust. Although these insecticides permitted profitable production of the crop, substantial yield losses occurred. Early planting of and early destruction of crop residues controlled the pink bollworm.

The advantage of calcium arsenate and sulfur was that they did not kill a great percentage of the insect enemies (parasites and predators) of cotton pests. As a result, outbreaks of two major secondary pests, the tobacco budworm and the bollworm [*Heliothis zea* (Boddie)], occurred only sporadically. (A secondary pest is one that attains crop-damaging numbers only when its natural enemies are decimated.)

Shortly after World War II the new synthetic chlorinated hydrocarbon insecticides, such as toxaphene, DDT, benzene hexachloride, endrin, and dieldrin became available for use on cotton. These had a spectacular effect on cotton production, since they provided almost complete control of the pest insects at an economical cost. Now cotton could be protected throughout the growing season, and 10 to 20 insecticide applications per growing season were common. Varieties were developed whose fruiting periods were more indeterminate, and irrigation and fertilizer were increased so that fruiting could be maintained longer. These practices resulted in major increases in yield.

On the surface, pest insect control in

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0036-8075/82/0402-0019$01.00/0

southern Texas was without problems. However, the organic insecticides applied to control the boll weevil also heavily decimated the insect enemies of the bollworm, and this pest became more common in cotton fields. The problem was solved by adding 1 to 2 pounds of DDT to the amount of boll weevil poisons used per acre.

In the mid-1950's the boll weevil developed resistance to the chlorinated hydrocarbon insecticides (*3*, *4*). Cotton producers solved this problem by switching to the organophosphorus insecticide methyl parathion. DDT was added to control the bollworm and tobacco budworm, since methyl parathion was highly lethal to their insect enemies but not effective against the worms at the dosage used. A mixture commonly used was 0.5 pound of methyl parathion and 1 to 2 pounds of DDT and toxaphene per acre.

By 1960 the bollworm and tobacco budworm had become difficult to control with DDT. Dosages were increased and treatments were applied at more frequent intervals. By 1965 these pests could no longer be controlled with DDT, endrin, toxaphene and DDT, Strobane and DDT, or the carbamate insecticides (*5–7*) (Table 1).

The problem of resistance by the bollworm and tobacco budworm to the above insecticides was partially resolved by increasing the dosage of methyl parathion to 1 to 2 pounds per acre and reducing the interval between treatments from 4 to 5 days to 2 to 3 days. The control produced was not as complete as that previously obtained with the DDT and methyl parathion mixture, but the treatment was deadly to the boll weevil, almost eliminating it from the cotton fields. The mixture was so effective against the boll weevil that producers no longer thought of it as the primary pest. The bollworm and budworm, the two secondary pests of the calcium arsenate days, had become the major pests of cotton in southern Texas (*8*).

By 1968 the tobacco budworm had developed resistance to methyl parathion (Fig. 1) and could no longer be controlled effectively with any available insecticide (*1*, *8*). Even though many fields were treated 15 to 20 times with all conceivable combinations of insecticides, severe damage was inflicted to cotton across the region. Many farmers suffered almost total losses, and plowed their cotton fields under without a harvest (*8*). The total acreage planted in cotton began its precipitous decline.

The emergence of a strain of tobacco budworm resistant to all insecticides rendered obsolete much of the technology then available for producing cotton. New pest management strategies involving far more limited use of insecticides had to be devised.

Table 1. Increase in the resistance of the bollworm and tobacco budworm to certain organochlorine and carbamate insecticides in southern Texas between 1960 and 1965 (*19*). Values for 1960 and 1961 are from Brazzel (*5*).

Compound	Median lethal dose (milligrams per gram of larva)			
	Bollworm		Tobacco budworm	
	1960	1965	1961	1965
DDT	0.03	1000+	0.13	16.51
Endrin	0.01	0.13	0.06	12.94
Carbaryl	0.12	0.54	0.30	54.57
Strobane and DDT	0.05	1.04	0.73	11.12
Toxaphene and DDT	0.04	0.46	0.47	3.52

Table 2. Per acre comparison of cotton production under different pest management systems in Frio County, Texas, in 1974 (*16*).

Item	Unit	Production technique			
			Cooperating producer		
		Typical*	Before change-over	Short season (40-inch gaps)	Short season (26-inch gaps)
Input					
Fertilizer	Pounds	120	178	72	72
Irrigation	Inches	20	18	12	12
Pesticides	Pounds	9.6	16.9	6.6	6.6
Total energy	Kilocalories × 10^3	3624	3624	2445	2445
Cost	Dollars	278	326	281	279
Cost	Cents per pound	47.60	42.56	33.84	26.90
Production					
Yield	Pounds	500	625	649	765
Gross†	Dollars	340	435	452	532
Net†	Dollars	62	109	170	252

*Based on data in (*17*). †Based on prices of $0.60 per pound for lint and $120 per ton for seed.

The Basis for the New System: Initial Efforts to Reduce Pesticide Use

The boll weevil and cotton fleahopper were the key pests responsible for the problem in the 1960's. The bollworm and tobacco budworm attained damaging numbers only when their natural enemies were killed with insecticides. The solution seemed obvious. Ways had to be devised to control the weevil and fleahopper without inducing outbreaks of the bollworm and budworm.

Research had shown (*9*, *10*) that the boll weevil might be controlled with least disruption to its insect enemies by a combination of measures applied during the harvest season and aimed at reducing the number of adults surviving the winter. These measures included (i) early planting, (ii) use of desiccants and defoliants to terminate the crop and cause shedding of fruit suitable for weevil food and reproduction, (iii) treating the cotton field once or twice with insecticides during the harvest period to kill as many diapausing weevils as possible, (iv) harvesting the crop rapidly, (v) destroying the stalks (this was already being enforced to control the pink bollworm), and (vi) plowing the residue under immediately thereafter. The number of diapausing boll weevils can be so reduced by these practices that damaging outbreaks do not occur during the subsequent season (*9*, *10*). Also, if farmers avoid insecticidal treatments during the early flowering of cotton, bollworms and tobacco budworms can often be controlled by their natural enemies.

The cotton fleahopper is most damaging at the time cotton begins to form squares (unopened flowers). Fortunately, several insecticides, when used at low dosages, destroy enough fleahoppers to allow cotton plants to fruit but do not kill great numbers of the fleahoppers' insect enemies. It also is possible to kill overwintering boll weevils during this period, before they can reproduce, with low dosages of these insecticides.

Reducing irrigation and fertilization to induce early maturation of the cotton crop is also effective, since damage inflicted by the boll weevil, bollworm, and tobacco budworm becomes greater as the season progresses. In addition, one can allow the pest population to grow somewhat larger before initiating insecticide applications, the rationale being that it is better to lose a little cotton to these pests than risk it all by killing their insect enemies.

A program entailing all these measures was implemented in the lower Rio Grande Valley in the fall of 1968. During the 1969 growing season, boll weevils did not multiply to damaging levels, insecticide treatments for this pest were not needed, and outbreaks of bollworms and budworms were averted. The number of insecticide applications was reduced more than 50 percent; many producers did not treat their fields at all. Yields were the second best in 20 years (*8*).

But in 1970 the number of cotton fleahoppers in the area was again extremely high. Cotton farmers had to use insecticides repeatedly, thereby inducing a severe outbreak of budworms and bollworms. Although some fields were treated 20 times or more, crop losses were severe and widespread—and farmers were losing confidence in their ability to produce cotton at a profit (*8*).

Development of the New System

Boll weevils are most vulnerable to insecticides during the harvest season and in the spring, before oviposition occurs. Diapause occurs during late summer and early fall in response to shorter days, cooler temperatures, and maturation of the cotton plant. The adults that emerge during this period are nonreproductive. They feed for several days on cotton fruit and then leave the fields for nearby woods or brushy areas, where they overwinter in leaf litter.

In southern Texas, the overwintering weevils reenter the cotton fields soon after the plants emerge. Reproduction begins as soon as the squares are big enough to support the feeding of the larvae. Generally, the first generation is too small to affect yield. Losses are inflicted by the large second and subsequent generations that develop if not controlled. The overwintering adults should be killed before they can reproduce by treating the cotton one to three times with insecticides before the squares are one-third their full size.

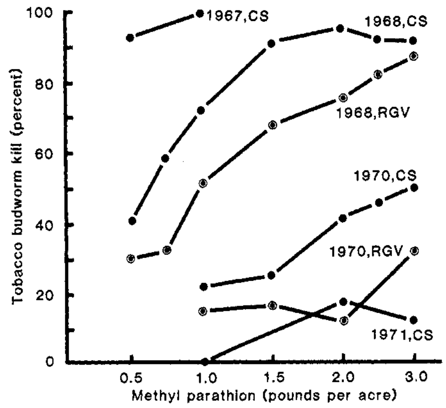

Fig. 1. Increase in resistance of the tobacco budworm to methyl parathion in the lower Rio Grande Valley (*RGV*) and near College Station (*CS*), Texas, between 1967 and 1971.

Knowledge of the boll weevil's life cycle guided the development of a more effective system of cotton pest management in the early 1970's. It was recognized that the system should include three basic components:

1) An areawide control program during the harvest season, combining prompt destruction of stalks and insecticidal treatment of harvested cotton fields to kill as many diapausing weevils as possible [earlier research (*11, 12*) has shown that if stalks are shredded and plowed under by mid-September, weevil numbers are so reduced that they cause negligible yield losses during the subsequent season].

2) Control of overwintered adults in the spring, before they can reproduce, by insecticides applied to cotton before the squares are of sufficient size to support development of the first-generation larvae (these treatments, which also control the cotton fleahopper, should be limited and timed to have the least impact on the insect enemies of the bollworm and tobacco budworm).

3) Cultivation of a rapid-fruiting, short-season cotton variety capable of setting a normal yield of bolls 12 days or older during the first 20 to 30 days of flowering (once a boll reaches 12 days of age, the carpel is so thick that it is safe from weevil attack) (*13*). Such a variety may be harvested in late July and August, before most of the weevils enter diapause.

The rationale for this "short-season" approach to cotton production in Texas is based on the work of Walker and Niles (*14*), who determined the relation between flowering rate in short- and long-season cotton and boll weevil damage (Fig. 2). The short-season variety can produce a much greater percentage of the bolls that produce the final yield during the first generation than an indeterminate variety. The first generation will be small if insecticides are used against the parents early in the spring. The full-season variety, because it fruits later and more slowly, has to set bolls during the period when weevils are most numerous if normal yields are to be attained. If the strategy of controlling overwintering boll weevils and growing a short-season variety is successful, there usually is no need for insecticide treatment of later generations of weevils or of other pests.

Fortuitously, one of us (L.S.B.) had initiated a program in 1963 to develop

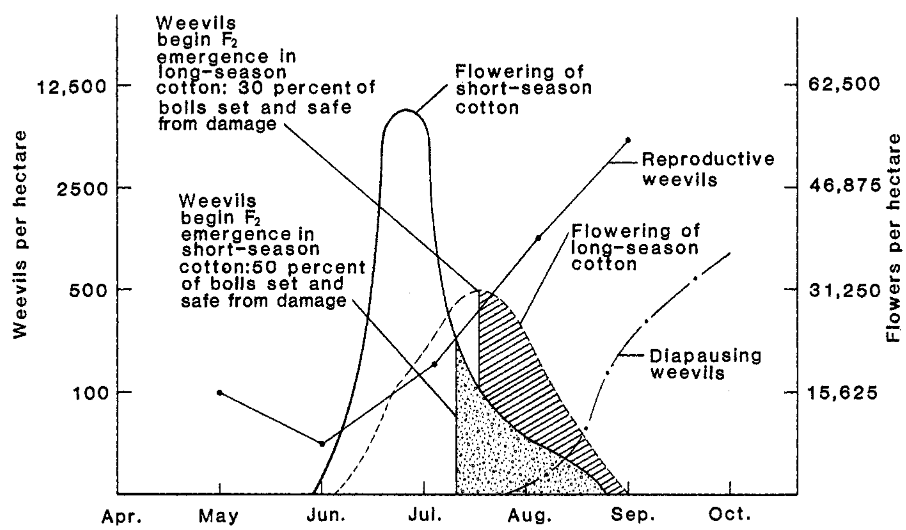

Fig. 2. Fruiting rates of short- and long-season cotton plotted against the boll weevil life cycle. The short-season variety sets bolls early and at a rapid rate, so that 50 percent or more of the yield is set before the second generation (F_2) boll weevils emerge. Only 30 percent of the bolls of the long-season variety are set during this period. Also, the short-season variety matures before many weevils enter diapause, while the long-season variety allows a substantial number to diapause.

cotton varieties whose seeds and seedlings tolerate cold and resist disease, especially blight caused by the bacterium *Xanthomonas malvacearum* (E. F. Smith) Dows. The first strains were tested from 1968 to 1970 and were released in 1973 as varieties TAMCOT SP-21 and TAMCOT SP-37 (*15*). These two varieties met the requirements of the integrated insect control system. Their cold tolerance and disease resistance permitted planting earlier in the season than conventional varieties. They fruited rapidly, retained a higher percentage of early fruit, and gave a normal yield 20 to 30 days earlier than conventional varieties. Moreover, they also were found to have a low level of resistance to the boll weevil.

Since then, varieties TAMCOT SP-21S, TAMCOT SP-37H, and CAMD-E have been released to growers (*15*). These have moderate levels of cold tolerance, resistance to seedling pathogens, and immunity to bacterial blight. In addition, they are moderately resistant to the cotton fleahopper. CAMD-E has moderate resistance to the boll weevil, bollworm, and tobacco budworm. TAMCOT SP-37H has low resistance to the boll weevil. TAMCOT SP-21S, because of its smooth leaf surface, is less heavily infested by the bollworm and tobacco budworm than varieties with hirsute leaves. These varieties have been widely accepted by Texas cotton growers and have greatly improved the efficacy of the new system.

Economic Benefits

One of the most striking demonstrations of the economic benefits of the new system was conducted in 1974 on a private farm in Frio County, Texas (Table 2). The typical cotton farmer in this county spent $278 to grow 1 acre of a conventional variety of cotton under irrigation in an area heavily infested with boll weevils (*16*). With a yield of one bale per acre, the net return was $62 per acre. The cooperating producer, one of the county's best cotton farmers, had been using more fertilizer and insecticide than the typical producer. His costs were greater ($326 per acre), but so were his yields, and the net return was $109 per acre. This farmer's land was used to grow a short-season variety (TAMCOT SP-37), and the amount of fertilizer, irrigation water, and insecticide was reduced 80, 50, and 60 percent, respectively. When the new variety was grown in rows that were spaced 40 inches apart (conventional spacing), the yield was increased over that of the conventional variety, the cost was $281 per acre, and the net return was $170 per acre. When the short-season variety was planted in rows 26 inches apart, the yield was greatly increased, the cost was the same, and the profit increased to $252 per acre. These results caught the attention of cotton farmers in the area and greatly accelerated their changing to the new system (*16*).

Using the new system, cotton producers have not been able to equal the magnitude of the increases in profit achieved in carefully managed demonstration plots, but they have done well. In coastal Texas, cotton yields have increased from 226 to 459 pounds of lint per acre since 1975. The average net return to the cotton producer has increased from $62 to $170 per acre (*18*). In the lower Rio Grande Valley, mean net return to producers of dryland cotton has increased $31 per acre. Insecticide use has decreased from 12.3 pounds of actual toxicant per acre to 1.5 pounds (*17*).

Most cotton farmers in Texas now practice some form of the new system. Insecticide use on cotton has been reduced from a high of 19.3 million pounds in 1964 to 2.3 million in 1976 (*18*). The system has made Texas cotton growers much more competitive economically and has led to a great resurgence of the industry in the state. Texas now produces about half of the nation's cotton.

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20. Supported in part by grants from the Rockefeller Foundation, the National Science Foundation, the Environmental Protection Agency, and Cotton, Inc.