B-1315

THE 'SHORT-SEASON EFFECT' in COTTON and ESCAPE from the BOLL WEEVIL

The Texas Agricultural Experiment Station, Neville P. Clarke, Director, The Texas A&M University System, College Station, Texas

CONTENTS

Historical Introduction 1

Experimental Procedure 7

Results 11

"The Short-Season Effect" 41

References Cited 45

SUMMARY

Experiments were conducted in Texas from 1975 through 1976 to investigate the place and value of rapid-fruiting cottons in production schemes directed at minimizing damage from the boll weevil, Anthonomus grandis Boheman. Narrow-row planting and the selection of certain genotypes produced more cotton bolls earlier in the season and increased yields. The benefits of genotype selection depended on the length of time during the bloom and boll set period that injurious numbers of weevils were delayed. Short-season types were more productive than their long-season counterparts in cases where the weevil-free period was shorter; however, where weevils were delayed the slower-fruiting cottons produced equally well. Susceptibility to boll-lock injury increased daily as bolls developed from later flowers following initiation of blooming. Seventy percent or more of the lint harvested (500-750 pounds of lint per acre) was produced from flowers of the first 3 weeks of blooming. It is during this critical time period that significant boll weevil damage to squares must be prevented if a satisfactory yield (500-750 pounds of lint per acre) is to be obtained without initiation of costly late-season insecticide applications.

KEYWORDS: Boll weevil/ Anthonomus grandis Boheman/ control/ cotton/ genetics/ short-season genotypes/ narrow-row planting/ age of cotton boll/ "short-season effect"/ Texas.

THE 'SHORT-SEASON EFFECT' IN COTTON

AND

ESCAPE FROM THE BOLL WEEVIL[1]

R. D. Parker, J. K. Walker, G. A. Niles

and J. R. Mulkey*

The tenure of Fredrick William Mally with the Agricultural and Mechanical College of Texas in College Station was a brief one of 3 1/2 years; but he left a cornerstone of research for viable cotton production that now extends over a significant amount of today's acreage. Entomology at the College began in 1899 with the arrival of Mally, who was engaged to develop a solution to the shocking destruction brought by a small, gray insect, the boll weevil, Anthonomus grandis Boheman. Erupting out of Mexico, this destructive cotton pest had struck through a large part of Texas by 1899, leaving little doubt that any of the cotton acreage of the Old South would escape. Mally's stewardship at the College, his research and extension programs, the recommendations he submitted, the rejection of these same recommendations by growers, and the slowly evolving boll weevil management practice during the next 70 years or so are thick with irony.

---

[1]Texas Agricultural Experiment Station, Texas A&M University. The work reported herein was funded by the Rockefeller Foundation and by an IBP sponsored project entitled "The Principles, Strategies, and Tactics of Pest Population Regulation and Control in Major Crop Ecosystems." This support was made available through a grant from National Science Foundation (NSF GB 34718) and a cooperative agreement with Agricultural Research Service, U. S. Department of Agriculture.
*Respectively, former graduate assistant (Department of Entomology), Texas A&M University, presently, entomologist, the Texas Agriculture Extension Service; associate professor (Department of Entomology), professor (Department of Soil and Crop Sciences), Texas A&M University, and associate professor, Texas A&M University (Agriculture and Research Extension Center at Uvalde).

Mally saw that every advantage was being surrendered to the boll weevil by the then present manner of cotton production. Oddly enough, the cotton plant itself exaggerated the abilities of the weevil. Varieties of those years were extremely slow to fruit, and somehow, this characteristic was related to increased losses. Moreover, the lateness of these cottons served the interests of weevils surviving the winter; it was only the fall generations of the pest, feeding on cotton that remained growing in fields, that survived to the following spring.

Mally's important recommendations, then, were these: plant early-maturing cottons (new developments at about this time) and destroy all cotton stalks promptly after harvest. Not entirely satisfied with Mally's guidance, growers made the scientist's position so unpleasant that he resigned in 1902.

If the quick change to faster-fruiting cottons seemed awkward for planters of 1900, the absence of the mechanics necessary and of the willingness to harvest cotton without delay and to promptly destroy stalks, stamped the researcher's recommendations as unworkable and out of the question. And yet, the thrust of later entomological findings by scientists from a number of quarters pointed to the wisdom of Mally's suggestions; in the final analysis it would be these recommendations, imperfect as they were, that permitted cotton production in the presence of the boll weevil. Improvement in the system would await the organic insecticides after World War II.

But what of this earliness in cotton -- an attribute that was observed to reduce losses by the weevil? How should it be measured? Not always tied to the newly introduced fast-fruiting varieties, earliness often seemed a function of the interaction of cotton with the soil on which it was grown. Alluvial, bottomland soil could grow a larger, more vigorously fruiting plant, but boll set might be slower, and ironically, weevil damage could be intensified. On the other hand, the less vigorous cottons of the upland soils fared better in their relationship with the weevil: more fruit could be set before weevils reached great populations. Numerous accounts of the conflict between the boll weevil and the cotton plant likened it to a race between the fruiting ability of the plant and the relentless increase of the insect's numbers. This "relentless" increase, occurring in those seasons when rainfall was abundant, often became even more dedicated. Where the cotton plant won the first lap or so of the race, bolls would be set and some production assured. The more bolls established before weevils increased to great numbers, the higher were the yields. Obviously, bolls were less vulnerable than squares. Earliness, when it operated to subdue weevil damage, likely was noted only after the fact; when at the conclusion of a growing season it became apparent that in a particular cotton field, in a given season, fruit set had been rapid and a reasonable yield had resulted despite the boll weevil. The reasons for or against these events occurring were at best only vaguely understood.

A number of agricultural scientists examined the matter (Bennet 1908, Ewing 1918, Cook 1923, Ware 1925, Verhalen et al. 1975); yet the descriptions of earliness in cottons and its interface with the weevil's numbers were not adequate to structuralize the interaction so that predictive extensions might follow. If studies provided generalities of this relationship, these fell short of the kind of delineation needed to more perfectly understand, and address, the problem of the pest.

The arrival of the organic insecticides after World War II seemed to relegate the idea of "earliness in cottons as a means to escape damage from the boll weevil" to a less prominent status. Whether cotton fruited rapidly or not, these economical and effective insecticides (applied in multi-applications) were the kind of solution that growers had long imagined. By 1964, over 19 million pounds of insecticides was being applied to cotton to guard against the boll weevil and other cotton insects. No longer was the boll weevil approached with the less-than-perfect cultural steps of Fredrick Mally. The scheme worked well until a series of events, evidence of the biological skills of the insect, showed themselves.

The development of insect resistance to pesticides, especially by the bollworm, Heliothis zea (Boddie), and the tobacco budworm, Heliothis virescens (F.), cut through the enthusiastic promise of multi-treatment programs and had, by the mid-1970's rerouted the strategies of pest control in cotton in Texas. In 1976, a little over 2 million pounds of insecticides was applied to the crop. Hardly a reroute at all, most of these "new" Texas schemes embrace the basic Mally tenets of the early years of this century.

Variously described, the new direction is more commonly referred to as "short-season cotton production." At the center of the scheme are cotton genotypes that, under a variety of soils and growing conditions, produce relatively high yields in a compressed fruiting period. Certain conditions enforce this fruiting habit: reduced nitrogen and the avoidance of late irrigation are important. It is widely held that the early squares are important and should not be lost to the cotton fleahopper, <u>Pseudatomoscelis seriatus</u> (Reuter), or to the boll weevil. A number of studies have demonstrated that short-season cotton production performs well (Heilman et al. 1977, Namken and Heilman 1973, Sprott et al. 1976); insecticides have been reduced and yields and profits increased. But the questions of why and under what circumstances the rapid-fruiting of cotton serves to limit weevil damage have remained unanswered.

Walker and Niles(1971) approached a solution to these mysteries in their model which characterizes the different effects of the boll weevil on both short- and long-season cottons where injurious infestation did not develop until the second generation, a period that starts about day 30 of the blooming period. In this model most blooming had occurred in the short-season cotton by day 30, and a substantial number of bolls (12 days or older) were established on plants. Bolls of these ages were presumed unsusceptible to weevil damage. On the other hand, the long-season cotton had bloomed less with a complement of younger bolls present than were on the short-season plant. Walker and Niles presented other data that inferred that a crop could escape major injury if overwintered weevil infestations were no larger than 20 females per acre. When numbers of the overwintered brood were increased beyond 60, damaging infestations appeared well before day 30, or before adequate boll set had been secured. This study established that the time of emergence of the first and second generations of weevils could be predicted by knowledge of the flowering pattern of cotton.

This model was tested (Walker et al. 1976), and the results demonstrated that, where weevils did not attain damaging numbers until the second generation, substantial production was realized, especially where new short-season cottons were used and planted in narrow-row configurations. Walker et al. (1977) later established the probabilities of injury to bolls of different ages present at the time weevils became severe in the second generation. It was concluded that "when weevils are delayed until the second generation, the level of boll damage may be more closely involved with the age distributions of the bolls. A production scheme that increases the number of older bolls (perhaps 12 days of age) by the time of the beginning second generation emergence would be less sensitive to weevil attack." This experiment illustrated the daily decline in susceptibility of cotton bolls. Bolls in the 12-day-or-older category escaped major losses of locks to the weevil.

The experiments reported herein were designed to explore and develop understandings of this "short-season effect" or the particular situation that permits effective cotton production where a combination of rapid-fruiting (and rapid boll set) and a delay in damaging numbers of the weevil until about day 30 of blooming exists.

EXPERIMENTAL PROCEDURE

Experiments were conducted during 1975 at a dryland Blackland site in Falls County in a 35-inch rainfall zone and during 1975-76 in Uvalde and Frio Counties, an area termed the Winter Garden. Rainfall is about 23 inches per annum in the Winter Garden; both irrigated and dryland culture are practiced. The objective was to evaluate, without late-seasonal insecticidal control, various components of short-season cotton production, i.e., genotype, planting configuration, irrigation (in the Winter Garden) and levels of insecticides for overwintered weevil control. Nitrogen was held to about 25 pounds per acre in all tests. During 1976 at the Uvalde location, a companion study was carried out where overwintered weevil insecticidal treatments were applied plus eight late-season applications. Boll weevils were the only major insects at the test locations, although a cotton plant disease did produce premature defoliation of certain genotypes at the Uvalde site in 1976.

The primary field design at these locations was a split plot with three or four replications. Main plots were two levels of overwintered weevil treatments (one or three applications in the Winter Garden and two or none in Falls County); the first was initiated at first one-third grown squares, and succeeding applications followed at four-to six-day intervals. Plots untreated or receiving a single application are designated T1, those treated twice or three times, T2. Main plots were divided into two in-season irrigation levels (I1 and I2) (Winter Garden); these were divided into three planting configurations -- single-drill plantings on 38-inch beds (S1), double-drill plantings on 38-inch beds (S2), and single-drill plantings on 25-1/3-inch beds (S3). The S2 and S3 configurations are generally termed "narrow-row plantings." The planting configurations were further divided into various numbers of cotton genotypes. At the Blackland site, main plots contained the two levels of overwintered weevil treatments; subplots contained genotypes. Only single-drill, 38-inch planting was used at the dryland Blackland location.

The genotype plots in these experiments were two rows wide for the 38-inch rows, and three rows wide for 25-1/3-inch rows; these were 50 feet long. The Falls County test was replicated four times; Frio County, three times; Uvalde (1975) four times; Uvalde (1976), three times. Twenty buffer rows were used to separate the two levels of insecticides; four buffer rows were planted between the irrigation levels.

A second experiment was planted in 1976 at Uvalde, and here full-season insecticidal treatment was applied: three early-season treatments and eight late-season. Three genotypes were examined in a randomized block design. Plots were 50 feet long, two rows wide; there were three replications.

The following is a description of the cotton genotypes examined. 1X6-56 is a small, compact, fast-fruiting cotton. 6M-10 is less compact than 1X6-56 and is intermediate in its rate of fruiting. 1209L and 1209 produce larger plants, have larger bolls than 1X6-56, and are slower to fruit. 407-79-R2 is a long-season, frego bract cotton. ORS-75C and OHR-74C are okra leaf-frego bract stocks that fruit very rapidly. Frego bract cottons have been shown to possess some resistance to the boll weevil.

Several commercial varieties were included in the tests. Lankart LX 571 is a widely planted cotton that, under dryland conditions and limited irrigation, fruits rather fast. TAMCOT SP-37, a variety well-adapted to South Texas, fruits quickly and yields well in dryland and irrigated cultures. Stoneville 213 is a long-season, relatively slow-fruiting variety that yields well under a high-input system.

Percentages of punctured squares and weevils per acre were determined from weekly examinations in each genotype subplot. Twenty-five squares were examined, and the row feet required to produce the 25 was measured; then, percentages of punctured squares and weevils per acre were calculated. Numbers of weevils per acre determined by fruit examination alone would, of course, underestimate the actual number. Before squaring, 150 row feet were examined on different dates to determine numbers of overwintered weevils. Adult weevil counts were not made at the Fall County test.

Seasonal blooming was recorded in 6-1/4-foot permanently marked sampling areas in each of the genotype subplots. Blooms were tagged and dated, permitting later examination for weevil damage when bolls were harvested. As the cotton boll has four or five locks, sometimes three, damage will be presented as percent damage to locks that originated on a certain day of blooming or during a period of blooming. Collections also were made at Uvalde in 1976 of tagged TAMCOT SP-37 bolls that had shed; these were examined for evidence of injury from weevil larvae.

Yields were determined from the 6-1/4-foot sampling areas where blooms were tagged. One to three harvests were made; these were ginned, and lint and seed weights were determined.

Where statistical differences were noted in the analysis of variance, means were separated at the 5-percent level of probability with Duncan's Multiple Range Test. Table 1 gives various information pertinent to the studies.

Table 1. Seasonal history of cotton experiments in Falls, Frio, and Uvalde Counties, 1975-76

County	Planting date	Date of first bloom	Date of insecticide treatment[a/] 1	2	3	Date of irrigation 1	2	Production se rainfall (i after plant
Falls	4/16/75	6/19	6/03[c/]	6/09				4.25
Frio	3/11/75	5/24	5/07	5/13	5/19	6/10	6/18	14.40
Uvalde	3/13/75	6/04	5/16	5/22	5/28	6/20	---[b/]	6.01
Uvalde	3/23/76	6/06	5/18	5/24	5/28	6/11	7/01	27.70
Uvalde[d/] (full-season treatment)	3/26/76	6/06	5/18	5/24	5/28	6/15	6/21	27.70

a/ Azinphosmethyl (0.25 lb AI/A).

b/ Rainfall negated the need for a second irrigation.

c/ Dicrotophos (0.1 lb AI/A) was used for fleahopper control on this date in plots untrea overwintered weevils.

d/ Azinphosmethyl at 0.25 lb AI/A and Pydrin at 0.125 lb AI/A were applied for each trea eight treatments were made beginning July 2.

RESULTS

Falls County, 1975. The boll weevil percent-punctured-square infestation was slow to develop at this location, and the percent-punctured squares never reached a high level; there was no statistical difference between plots treated twice for overwintered weevils or untreated. Percent-punctured-square count on day 28 of the blooming period was less than 20 percent (Table 2).

Ten genotypes were planted at this test site; however, we selected only three for critical examination - the commercial variety Lankart LX 571, 1X6-56 and the frego bract genotype ORH-74C. There were no significant differences in the fruiting between genotypes due to insecticidal treatment; the means presented are an average of the two treatment levels.

There were no significant differences in yields due to genotype (Table 2). Over 80 percent of the bolls of all cottons harvested were from flowers set by July 8 (Table 2); that is, from flowers produced during the first 20 days of flowering. Lock damage from weevils was low in locks developing from flowers of the first 18 days of blooming and gradually increased after this (Figure 1). The percent-lock damage for the season averaged across treatments and genotypes was about 9 percent. Lankart LX 571 produced fewer bolls than the other cottons, but this cotton possesses a larger boll.

Figure 2 shows the rapid accumulation of bolls 10 days or older that occurred for Lankart LX 571. By about day 30 of the blooming period, 90 percent of the bolls to be harvested (about 90 percent of 539 pounds per acre) were 10 days old or older. In a brief period of 10 days, from day 19 of blooming to day 29, the major part of the crop

Table 2. Percent-punctured squares, yields of cotton, and numbers of bolls harvested (1000s/A) from different flowering periods, Falls County, 1975[a/]

	% Punctured squares[b/]							
	6/17		6/26		7/10		7/17	
Genotype	T1	T2	T1	T2	T1	T2	T1	T2
ORH-74C	0	0	2	2	5	12	17	15
Lankart LX 571	0	0	0	1	12	15	18	17
1X6-56	0	0	0	0	10	17	14	16

	Pounds lint/A
ORH-74C	459
Lankart LX 571	539
1X6-56	431

Numbers of harvested cotton bolls from different flowering periods and (%) of these of total

Genotype	6/19-23	6/24-28	6/29-7/03	7/04-08[c/]	7/09-13	Total
ORH-74C	8 (6%)	14(10%)	49(34%)	52(35%)	23(16%)	146 a
Lankart LX 571	10 (8%)	21(19%)	40(35%)	32(28%)	11(10%)	115 b
1X6-56	17(12%)	18(13%)	40(30%)	40(27%)	25(18%)	137 a

a/ Means are compared vertically; those sharing a common letter are not significantly different (P=0.05).

b/ Data not analyzed.

c/ Day 20 of blooming.

Figure 1. Percent of locks damaged by boll weevils from flowers occurring on different days of the blooming period, Falls County, 1975.

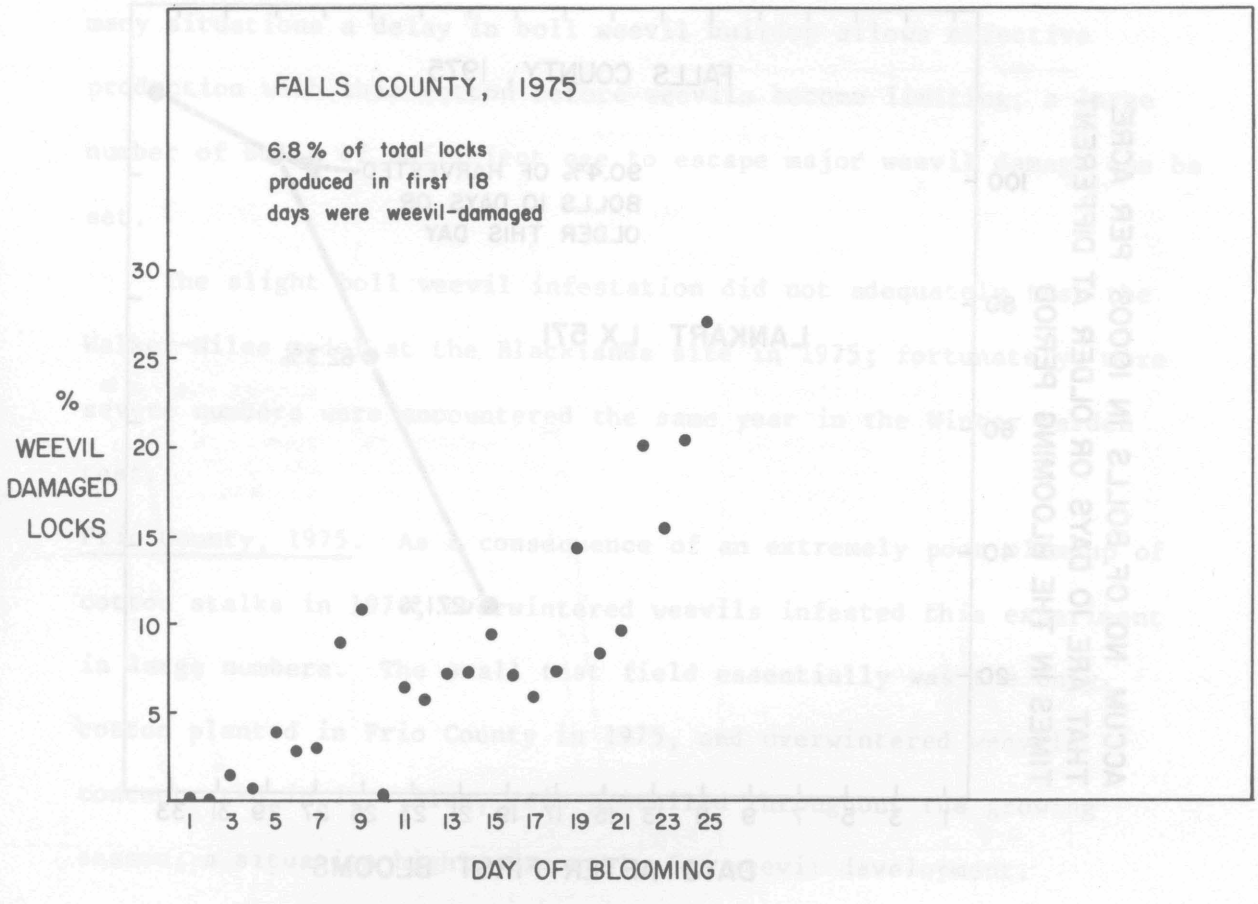
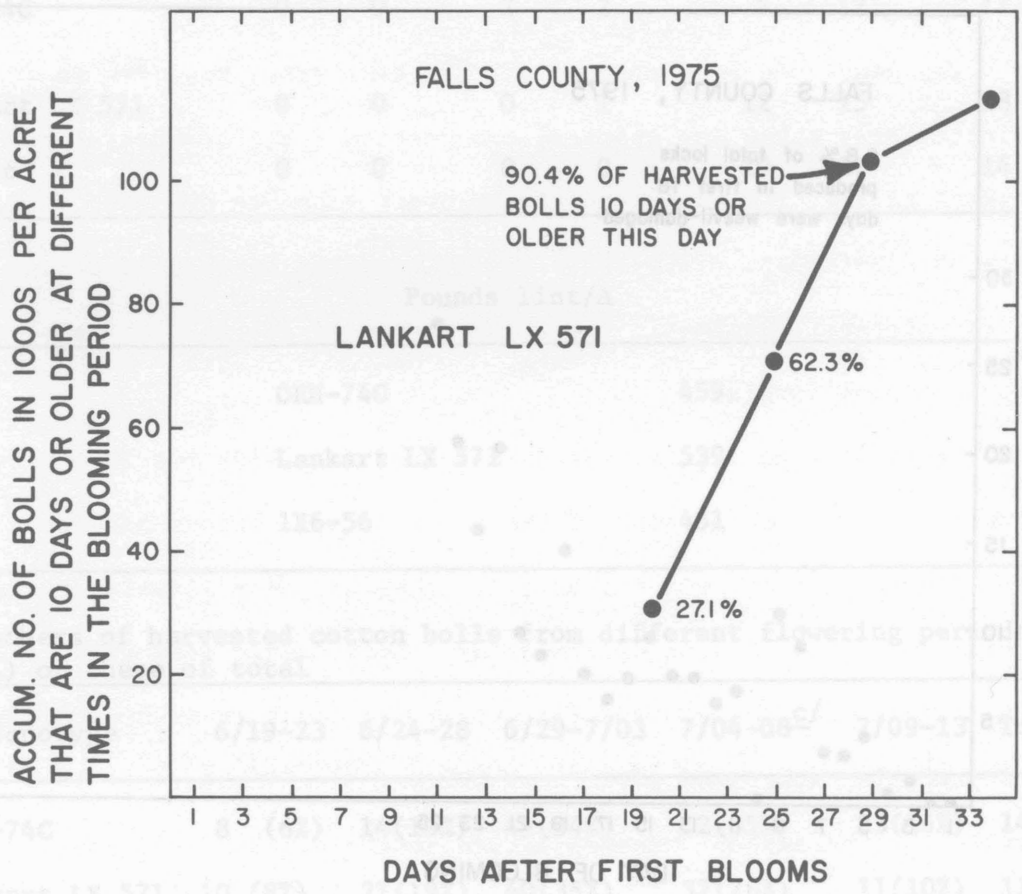


Figure 2. Accumulated bolls (10 days or older) and percent of these of total harvested, at different days of the flowering period, Falls County, 1975.



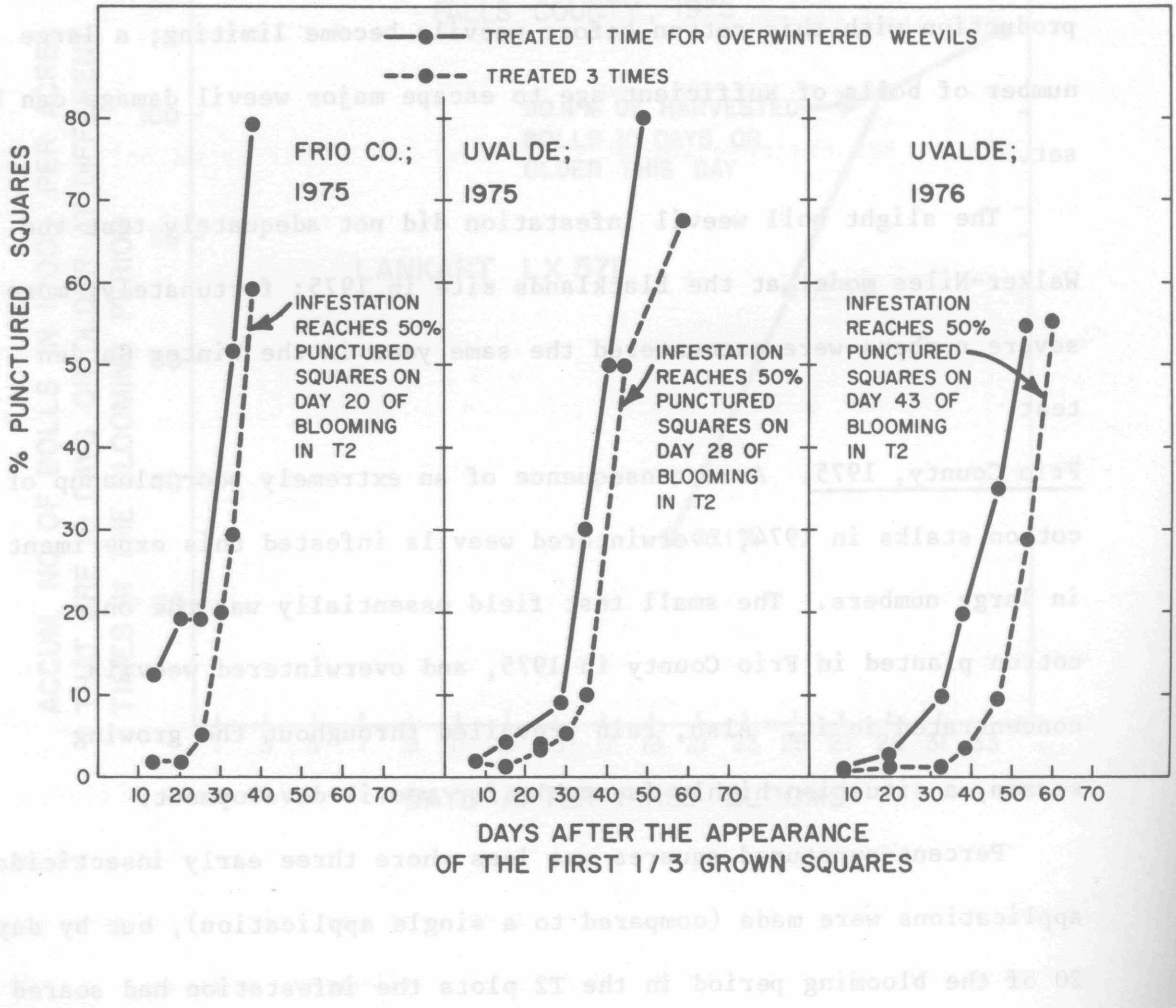
in bolls attained 10-day-old-or-older status. This compares favorably with the short-season cotton of the Walker-Niles model; had weevils in the present Blacklands test become severe around day 30 of blooming, lock damage according to the model should not have been severe. The rapid-fruiting performance of Lankart LX 571 explains its wide use on certain soil types in Texas and under certain production schemes. In many situations a delay in boll weevil buildup allows effective production with this cotton before weevils become limiting; a large number of bolls of sufficient age to escape major weevil damage can be set.

The slight boll weevil infestation did not adequately test the Walker-Niles model at the Blacklands site in 1975; fortunately, more severe numbers were encountered the same year in the Winter Garden test.

<u>Frio County, 1975</u>. As a consequence of an extremely poor cleanup of cotton stalks in 1974, overwintered weevils infested this experiment in large numbers. The small test field essentially was the only cotton planted in Frio County in 1975, and overwintered weevils concentrated in it. Also, rain prevailed throughout the growing season, a situation highly favorable for weevil development.

Percent-punctured squares was less where three early insecticidal applications were made (compared to a single application), but by day 20 of the blooming period in the T2 plots the infestation had soared to 50 percent (Figure 3). Significantly (P=.05) fewer squares were punctured per acre through the first 10 days of blooming in the T2. There was evidence that, in addition to infesting the T2 plots between applications of insecticide, overwintered weevils were continuing to

Figure 3. Percent punctured squares at different points in time of the squaring period at three locations, 1975-1976 (T1 = one treatment; T2 = three treatments).



colonize after the final treatment. For about 28 days after appearance of the first squares, the infestation was considerably less in T2 than in T1. Numbers of overwintered and summer generation weevils per acre appear in Table 3; the infestation was less in the T2 plots. The reductions in weevil numbers and square damage made a great difference in blooming between the two levels of treatment (Table 3). Significant increase of blooms resulted from an additional in-season irrigation; substantial increases were attributable to S2 and S3 planting and to genotype.

The effect of these variables on numbers of harvested bolls is shown in Table 3. Trends are similar to those recorded for blooms.

The variable of three overwintered weevil treatment had the most powerful effect in increasing yields (Table 3), but irrigation, S2 and S3 spacings, and genotypes also produced positive, additive increases. The benefits of the quicker-fruiting TAMCOT SP-37 and 1X6-56 are apparent.

Exploding populations of weevils appeared too early in the blooming period (even in the T2 plots) to allow for the accumulation of bolls of sufficient age to escape major damage. This is apparent in Table 3. However, percent damage to locks in bolls from different flowering intervals is less in T2 plots. It is striking that yields in excess of 500 pounds of lint per acre were realized, considering the magnitude of lock injury. Harvested, undamaged locks as influenced by insecticidal treatment appear in Figure 4. Only a small percent of the harvest came from blooms after the first 18 days of flowering.

This experiment underlines the importance of the transition in

Table 3. Number of weevils per acre, accumulated blooms from different periods, total bolls harvested, and yields in pounds of lint per acre; total locks harvested and percent of these damaged by boll weevils. Frio County, 1975 [a/] [b/]

	Number of weevils/A [c/]	
	T1	T2
May 21	367	0
May 27	459	183
June 16	6093	1123
June 23	3172	3900

Accumulated blooms (1000s/A)			
	May 24-June 4	June 5-11	June 12-23
T1	36.6 e	107.6 e	225.4 e
T2	60.2 f	179.3 f	358.9 f
I1	44.7 e	136.6 e	284.2 e
I2	52.0 f	150.3 f	300.2 f
S1	36.4 e	107.0 e	228.2 e
S2	58.6 f	165.6 f	321.2 f
S3	50.3 f	157.7 f	327.2 f

Table 3 (continued)

6M-10	44.1 e	126.2 e	255.2 e
1X6-56	57.5 f	160.6 g	309.2 f
TAMCOT SP-37	43.6 e	143.5 f	312.1 f

Total bolls (1000s/A) harvested

T1	121.0 e
T2	217.9 f
I1	159.2 e
I2	179.7 f
S1	141.9 e
S2	175.6 f
S3	190.7 f
6M-10	145.0 e
1X6-56	179.6 f
TAMCOT SP-37	183.8 f

Pounds lint/A

	S1	S2	S3	Mean
T1	132	163	168	154 e
T2	455	541	535	511 f
Mean	294 a	352 b	352 b	

Table 3 (continued)

	Genotype			
	6M-10	1X6-56	TAMCOT SP-37	Mean
I1	275	309	334	306 e
I2	309	407	361	359 f
Mean	292 a	358 b	348 b	

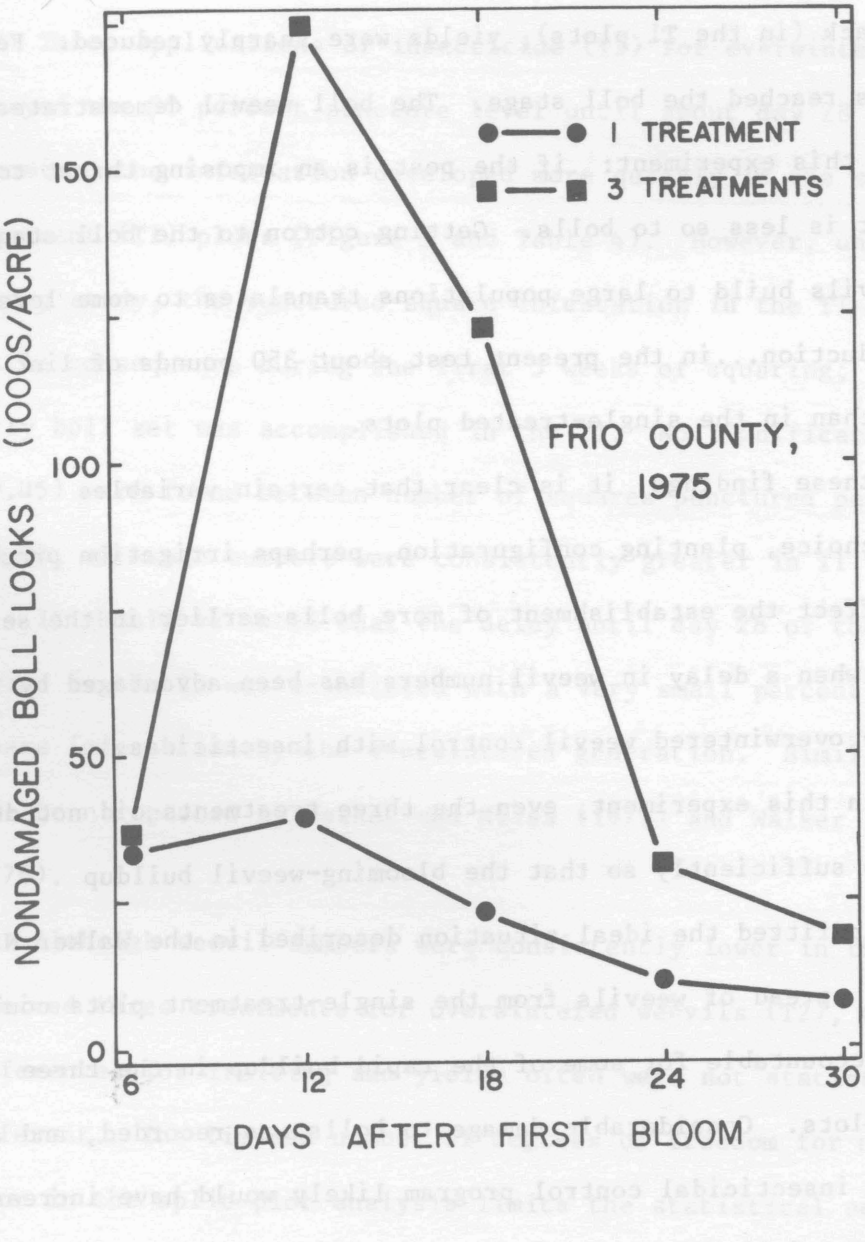
Blooming interval	Total locks produced (1000s/A[d/])		Damaged boll locks (%)	
	T1	T2	T1	T2
May 25-31	50	42	29.0	18.8
June 01-06	103	265	57.4 b	31.6 a
June 07-12	186	304	87.8 b	61.8 a
June 13-18	106	137	90.6	78.3
June 19-24	42	118	78.8	82.8

a/ Means followed by a, b are compared horizontally; those followed by e, f, g are compared vertically. Means sharing a common letter are not significantly different (P=0.05).

b/ First blooms appeared by May 24.

c/d/ Not statistically analyzed.

Figure 4. Numbers of locks escaping weevil injury from different flowering periods, Frio County, 1975 (T1 = one treatment; T2 = three treatments).



cotton from squaring to the boll stage in escaping yield losses to the boll weevil. It is evident that three insecticidal treatments protected many more squares until they bloomed; and once fruits were in the boll stage, a surprising level of production occurred. Though damage to bolls was ample, many good locks matured and were harvested.

On the other hand, where blooms were greatly reduced by way of square attack (in the T1 plots), yields were sharply reduced. Fewer fruit forms reached the boll stage. The boll weevil demonstrates its duality in this experiment: if the pest is an imposing threat to squares, it is less so to bolls. Getting cotton to the boll stage before weevils build to large populations translates to some level of cotton production...in the present test about 350 pounds of lint per acre more than in the single-treated plots.

From these findings, it is clear that certain variables (genotype choice, planting configuration, perhaps irrigation practice) can also affect the establishment of more bolls earlier in the season, especially when a delay in weevil numbers has been advantaged by the appropriate overwintered weevil control with insecticides.

Yet, in this experiment, even the three treatments did not delay the weevils sufficiently so that the blooming-weevil buildup relationship fitted the ideal situation described in the Walker-Niles model. The spread of weevils from the single-treatment plots could have been accountable for some of the rapid buildup in the three treatment plots. Considerable damage to bolls was recorded, and a late season insecticidal control program likely would have increased yields substantially.

Fortunately, the weevil infestation in the experiments conducted in Uvalde County in 1975 was of less amplitude. Here, the insect's population development more nearly fitted the Walker-Niles model.

Uvalde County, 1975. The field design was similar to the Frio County test, but certain changes were made: a heavy rain negated the need for a second in-season irrigation, and the S3 stand of plants was so poor that these plots were discarded. The same cottons tested at Frio County were planted at Uvalde, plus an additional genotype, 1209L.

Three applications of insecticide (T2) for overwintered weevils delayed the 50 percent puncture level until about day 28 of the blooming; the infestation developed more quickly in the single treatment (T1) plots (Figure 3 and Table 4). However, unlike the Frio County study, the punctured-square infestation in the T1 plots was of little consequence during the first 5 weeks of squaring; substantial early boll set was accomplished in the T1. No significant differences (P=.05) were found between number of squares punctured per acre in T1 and T2, although numbers were consistently greater in T1.

It should be noted that the delay until day 28 of the blooming period in the T2 was associated with a very small percent-punctured-square infestation by the overwintered generation. Similar findings have been reported by Walker and Niles (1971) and Walker et al. (1976).

Although weevil numbers were consistently lower in the plots that received three treatments for overwintered weevils (T2), the mean differences for fruiting and yields often were not statistically different. The limited number of degrees of freedom for main-plot error in the split-plot analysis limits the statistical sensitivity

Table 4. Number of weevils per acre, accumulated blooming from different periods, number of bolls harvested, and yields in pounds of lint per acre, Uvalde County, 1975 a/b/

	No. of weevils/A c/					
	June 13	June 18	June 24	July 2	July 8	July 15
T1	0	0	3800	3500	2600	4300
T2	0	0	1200	1300	1500	3700

	Accumulated blooms (1000s/A)			
Blooming interval	6M-10	1X6-56	1209L	TAMCOT SP-37
June 04-21	122.6 a	184.1 b	162.0 b	189.3 b
June 22-27	228.8 a	333.4 bc	305.9 b	353.5 c
June 28-July 15	393.6 a	485.4 b	491.1 b	592.9 c

	Accumulated blooms (1000s/A)	
Blooming interval	S1	S2
June 04-21	113.8 a	215.1 b
June 22-27	229.0 a	381.8 b
June 28-July 15	413.5 a	568.0 b

	Accumulated blooms (1000s/A)	
Blooming interval	T1	T2
June 04-21	155.2	173.7
June 22-27	296.1	314.7
June 28-July 15	450.7	530.8

Table 4 (continued)

	Number of bolls harvested (1000s/A) from different blooming periods and (%) of total harvested from first 26 days of flowering					
	June 6-11	June 12-17	June 18-23	June 24-29		June 30-July 5
6M-10	6.7	27.1 e	57.2 e	42.9 e	(84%)	18.6
1X6-56	21.3	44.0 ef	89.6 f	41.7 e	(92%)	8.3
1209L	14.6	40.7 ef	84.9 f	56.7 ef	(92%)	12.2
TAMCOT SP-37	18.7	59.0 f	101.4 f	66.6 f	(88%)	21.2
S1	11.1	30.3 e	70.8 e	51.1		18.2
S2	19.5	55.1 f	95.7 f	52.8		12.0

Pounds of lint/A harvested

Harvest no.	Days after planting	lb lint/A (S1)	lb lint/A (S2)
1	144	190 a	337 b
2	153	305	333
3	160	117	105
Total		612 a	775 b

Harvest no.	Days after planting	lb lint/A 6M-10	1X6-56	1209L	TAMCOT SP-37
1	144	106 a	330 c	228 b	390 c
2	153	267	312	355	344
3	160	145 b	63 a	138 b	95 a
Total		518 a	705 b	721 bc	829 c

Table 4 (continued)

	lb lint/A			
	T1		T2	
Genotype	S1	S2	S1	S2
6M-10	362	605	458	649
1X6-56	601	619	786	815
1209L	619	810	565	892
TAMCOT SP-37	667	775	840	1034
Mean	632		754	

[a/] Means followed by a, b are compared horizontally; those followed by e, f are compared vertically. Means sharing a common letter are not significantly different (P=0.05).

[b/] First blooms appeared June 4.

[c/] Data not statistically analyzed.

of main plots (levels of overwintered treatment in this case) and differences may be obscured. The lower-level plots, however, often did show differences: planting configuration and genotype produced clear statistically validated effects. Table 4 gives the blooming performance as this expression was influenced by genotype, planting configuration, and overwintered weevil treatments. The rapid-fruiting of 1X6-56 and TAMCOT SP-37 and the advantage of S2 planting are apparent. Although blooming was favored in the T2 plots, the advantage was not statistically established.

Numbers of harvested bolls as influenced by planting configuration and genotype appear in Table 4. Results document the earliness of the S2 plantings and the more rapid fruit set in certain genotypes.

Over 80 percent of the bolls harvested for all genotypes arose from flowers appearing in the first 26 days of blooming (Table 4). Over 70 percent were harvested from the blooms of the first 21 days.

Earliness and increased yield were associated with the S2 plantings; and statistical advantage is noted in certain genotypes (Table 4).

Greater yields generally were associated with the T2 (Table 4), but these increases were not significantly different from the T1. A striking comparison can be noted between the slow-fruiting 6M-10, treated one time for overwintered weevils and planted on 38-inch centers, and the fast-fruiting TAMCOT SP-37, treated three times and planted in S2.

Damage to locks produced during the first 30 days of flowering for the two levels of overwintered treatment was obviously less in the T2 (Figure 5). Note that each day later a flower appears in the fruiting period after day 15, the higher the injury to the locks developing from that flower. Damage was low in locks that arose from flowers of the first 15 days of blooming. Fifteen percent of the locks that resulted from flowers of the first 21 days of blooming showed weevil injury in the T2 (Figure 5).

The rapid accumulation of bolls of different ages that was measured in TAMCOT SP-37 treated three times and planted in the S2 arrangement is illustrated in Figure 6. By day 21 of blooming, this cotton possessed a complement of bolls that would be 9 days or older at day 30 of blooming, and these yielded approximately 750 pounds of lint per acre. Although the weevil infestation, in terms of square attack, was sharply increasing by day 28 of blooming, many locks of younger bolls escaped attack; that is, those bolls that would be younger than 9 days at day 30 of blooming added somewhat more than 250 pounds of lint per acre. This occurred despite much increased lock damage.

As in the Falls County test, a relatively large number of bolls quickly attained ages that put them past the full force of weevil attack on this short-season variety (Figures 5 and 6).

<u>Uvalde County, 1976; Overwintered Weevil Treatments Only.</u> Boll weevil infestations were lighter at this location than the year before, and the 50-percent-punctured-square level was delayed until 43 days into the blooming period in the T2 plots. It attained the same level in the T1 in 36 days (Figure 3). Only on three dates were significant differences (P=.05) found in numbers of squares punctured per acre although counts were consistently greater in the T1. Numbers of

Figure 5. Percentages of locks damaged by weevils that arose from different days of flowering (averages of locks from all genotypes and spacings), Uvalde County, 1975 (T1 = one treatment; T2 = three treatments).

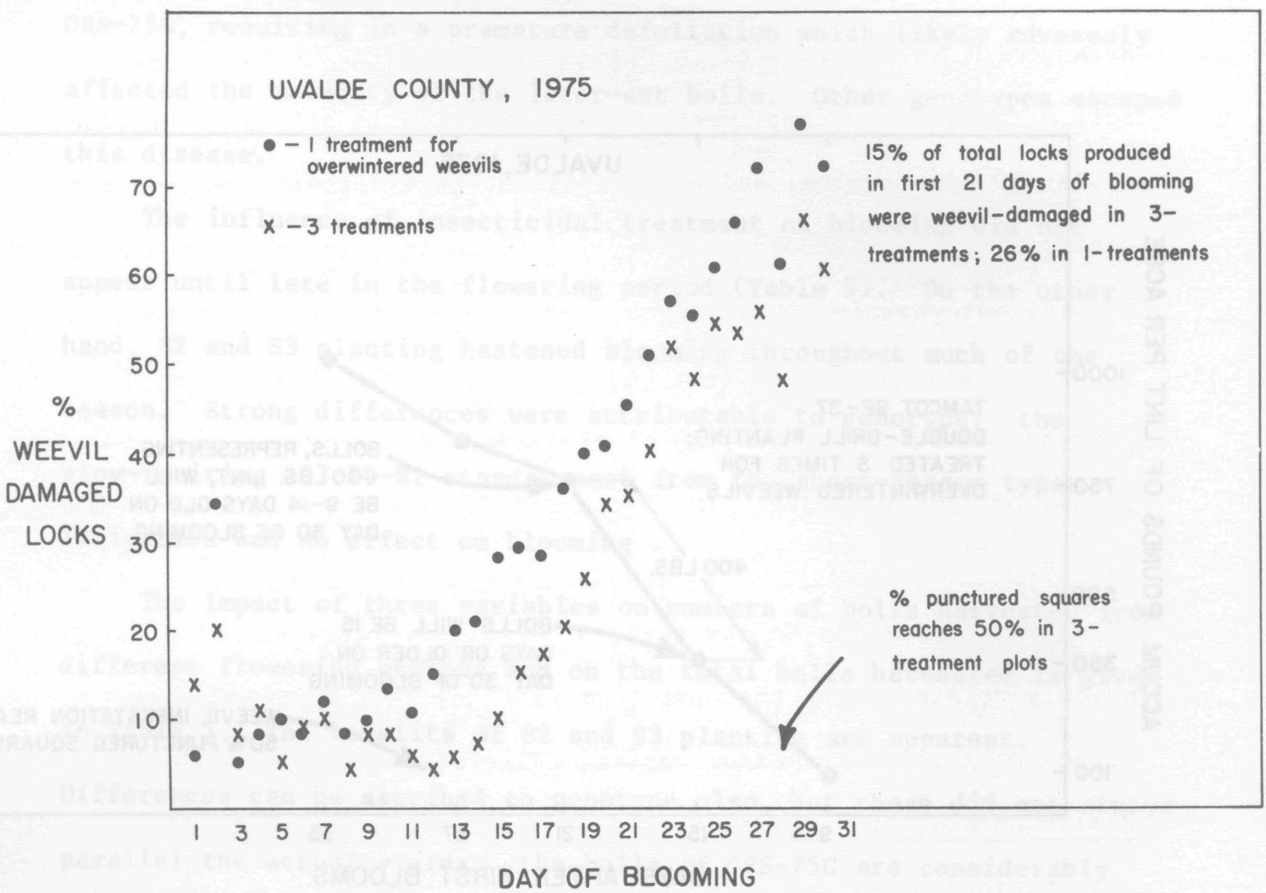
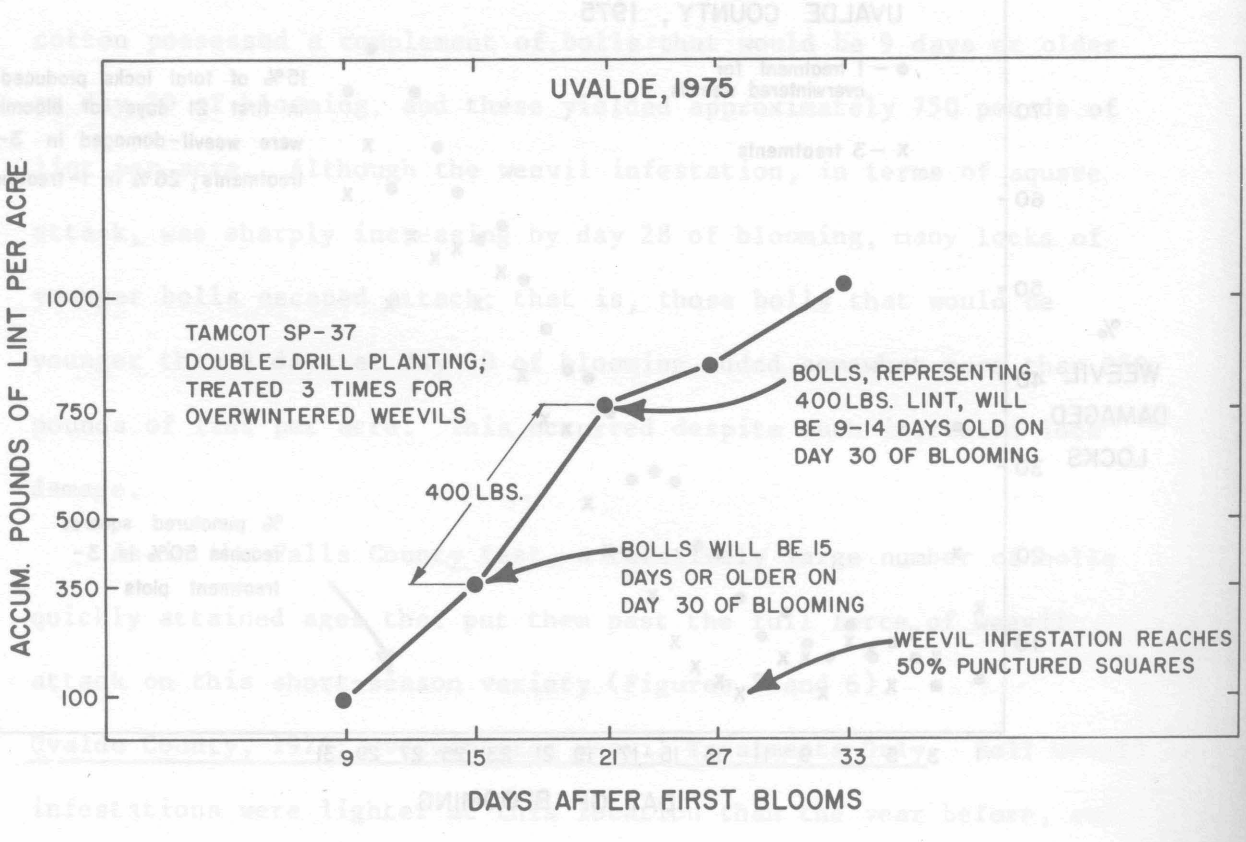


Figure 6. Accumulated pounds of lint in S2 planting of TAMCOT SP-37, treated three times, that arose from flowers produced in different periods; and ages of bolls on different days of the blooming period, Uvalde County, 1975 (T2 = three treatments).



weevils per acre appear in Table 5; large numbers were first recorded in T1 about 30 days into blooming. After mid-June, numbers of punctured squares per acre in the two frego bract cottons were significantly less (P=.05) than in the normal bract genotypes. The relatively long weevil-free period in all cottons allowed even the slow-fruiting genotypes to develop much of their yield potential.

It was a wet year at this test site, rain falling on every day from July 4 through 15. A leaf disease struck TAMCOT SP-37 and ORS-75C, resulting in a premature defoliation which likely adversely affected the maturity of the later-set bolls. Other genotypes escaped this disease.

The influence of insecticidal treatment on blooming did not appear until late in the flowering period (Table 5). On the other hand, S2 and S3 planting hastened blooming throughout much of the season. Strong differences were attributable to genotype: the slow-fruiting 407-70-R2 stands apart from the short-season types. Irrigation had no effect on blooming .

The impact of three variables on numbers of bolls harvested from different flowering periods and on the total bolls harvested is given in Table 5. The benefits of S2 and S3 planting are apparent. Differences can be ascribed to genotype also, but these did not always parallel the actual yields: the bolls of ORS-75C are considerably smaller than those of 1209 and 1209L; and the premature defoliation in ORS-75C and TAMCOT SP-37 could have reduced weights of bolls.

Shedding of bolls of TAMCOT SP-37 that were formed from flowers of the first 36 days of blooming averaged about 200,000 per acre. Of these, 11 percent contained an immature stage of the boll weevil or

Table 5. Number of weevils per acre, accumulated blooms from different periods, number of bolls harvested that were set in different periods and yields in pounds of lint per acre, Uvalde County, 1976[a/b/]

Number of weevils per acre

Date	T1	T2[c/]
May 25	48	0
31	55	0
June 3	0	0
7	42	191
10	51	0
15	0	127
17	414	0
23	934	0
29	442	499
July 7	1,935	704
14	3,304	610
20	5,668	1,118

Number of accumulated blooms (1000s/A)

	June 6-11	June 12-23	June 24-29	June 30-July 14
T1	11.2	221.5	410.4	581.4 e
T2	11.8	217.2	420.4	662.5 f

Table 5 (continued)

S1	5.7 e	145.4 e	309.3 e	516.0 e
S2	13.1 f	266.9 f	475.1 f	655.9 f
S3	15.7 g	245.7 f	461.9 f	693.4 g
1X6-56	13.2 f	222.1 f	405.1 g	580.8 ef
1209L	5.9 e	199.2 f	370.4 ef	559.7 e
1209	14.8 f	217.3 f	381.4 efg	566.4 ef
ORS-75C	19.3 g	308.8 g	585.2 h	859.8 g
407-79-R2	4.4 e	169.2 e	356.3 e	567.8 ef
TAMCOT SP-37	11.4 f	199.4 f	394.2 fg	597.3 f

Number of bolls (1000s/A)

Treatment variable	June 6-14	June 15-20	June 21-26	June 27-July 2	July 3-14
T1	32.2	68.4	96.2	47.6 e	14.8 e
T2	31.9	71.5	96.1	62.2 f	29.0 f
I1	31.1	69.0	92.4	56.4	24.8
I2	33.0	70.9	99.8	53.4	19.0
S1	18.5 e	50.0 e	86.9	64.5 f	27.1
S2	39.9 f	85.0 f	99.6	44.1 e	16.1
S3	37.7 f	74.7 f	101.9	56.1 e	22.6
1X6-56	43.5 fg	68.4	104.1 f	51.8 ef	15.6 ef
1209L	24.3 ef	61.9	92.1 f	45.1 ef	26.8 ef
1209	30.3 ef	69.5	68.0 e	52.4 ef	24.2 ef

Table 5 (continued)

ORS-75C	49.9 g	75.6	130.4 g	37.2 e	10.8 e
407-79-R2	13.7 e	70.5	72.8 e	85.0 g	31.9 f
TAMCOT SP-37	30.5 efg	73.6	109.3 f	58.0 f	22.3 ef

	Lbs. lint/A			
	S1	S2	S3	Mean
1X6-56	886	945	1,076	969 fg
1209L	882	921	971	925 ef
1209	968	990	1,124	1,027 g
ORS-75C	829	980	939	916 ef
407-79-R2	889	971	1,071	977 fg
TAMCOT SP-37	839	828	943	870 e
Mean	882 a	939 b	1,021 c	

	I1	I2	Mean
T1	975 b	865 a	921
T2	972	975	973
Mean	973 b	921 a	

a/ Means followed by a, b, c are compared horizontally; means followed by e, f, g are compared vertically. Those sharing a common letter are not significantly different (P=0.05).

b/ First blooms appeared June 6.

c/ Data not analyzed.

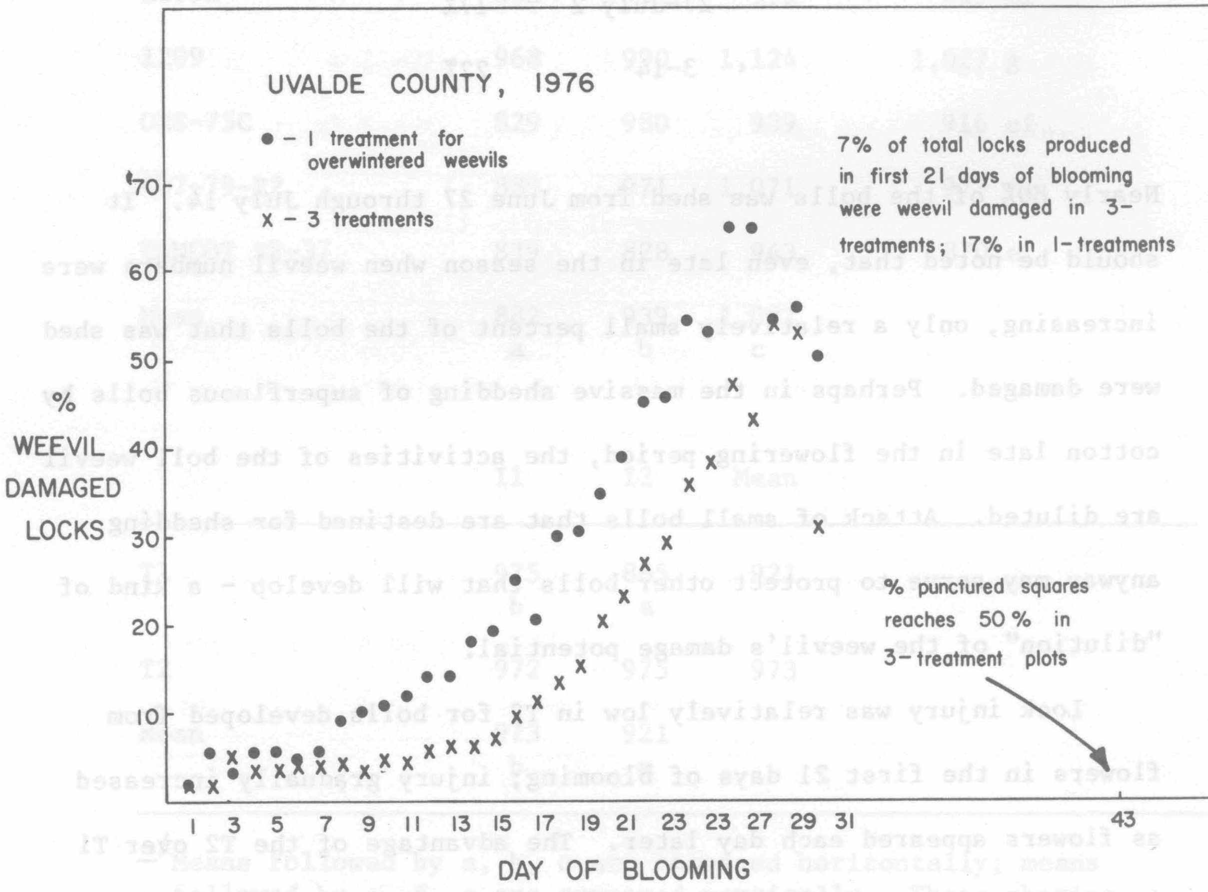
evidence of larval damage; the remainder, nearly 90 percent, was lost from the plants apparently from natural shed. Percent shed of bolls averaged across T1 and T2, originating in 6-day blooming periods and containing weevil stages or damage, were as follows:

June	9-14	2%
	15-20	4%
	21-26	9%
	27-July 2	17%
	3-14	22%

Nearly 80% of the bolls was shed from June 27 through July 14. It should be noted that, even late in the season when weevil numbers were increasing, only a relatively small percent of the bolls that was shed were damaged. Perhaps in the massive shedding of superfluous bolls by cotton late in the flowering period, the activities of the boll weevil are diluted. Attack of small bolls that are destined for shedding anyway may serve to protect other bolls that will develop - a kind of "dilution" of the weevil's damage potential.

Lock injury was relatively low in T2 for bolls developed from flowers in the first 21 days of blooming; injury gradually increased as flowers appeared each day later. The advantage of the T2 over T1 is apparent (Figure 7). Although lock injury increased daily after day 21 of flowering, slow-fruiting genotypes produced a considerable amount of cotton through day 27 of blooming. Approximately 70 percent of the locks in T2 originated from flowers produced in the first 21 days of blooming and by day 27, 90 percent.

Figure 7. Percentages of locks damaged by weevils that arose from different days of flowering (averages of locks from all genotypes, irrigations, and spacings), Uvalde County, 1976 (T1 = one treatment; T2 = three treatments).



A comparison of the locks harvested that arose from different blooming periods in ORS-75C and in the slower-fruiting 1209L is presented in Figure 8. Although the actual damage per acre to locks is similar regardless of genotype or spacing at several points in the season, the short-season ORS-75C accumulated locks at a more rapid rate. A large percent of the harvest in this genotype planted in the S2 originated during the first 21 days of blooming. This figure was developed from the T1 where 50 percent punctured squares was delayed until about day 36 of blooming.

The more slowly developing weevil infestation in T2 was not associated with increased production (Table 5). An additional irrigation (I2) decreased yields, but only where a single overwintered treatment was made, possibly a consequence of the interaction of a more rapidly building boll weevil infestation and a delay in maturity of the cottons where the second watering had been administered. The two narrow-row-plantings enhanced yields.

The S2 and S3 plantings produced significantly (P=0.05) more lint in the first harvest than did the S1 (about 70-100 pounds of lint per acre more). Also, TAMCOT Sp-37, ORS-75C, and 1X6-56 yielded, in the first harvest, over 200 pounds of lint per acre more than did the slower-fruiting 407-79-R2 and 1209L (P=0.05).

Harvested locks (and lint) for the slower-fruiting 407-79-R2 and the short-season TAMCOT SP-37 are compared in Figure 9. Note that in these T2 plots, where the 50-percent-punctured-square level was not reached until day 43 of flowering, that over 400 pounds of lint per acre was realized in 407-79-R2 from blooms that appeared from days 22 through 23 of the blooming period. Although the percent damage to

Figure 8. Numbers of locks that arose from different flowering periods in two genotypes treated once for overwintered weevils, Uvalde County, 1976 (T1 = one treatment).

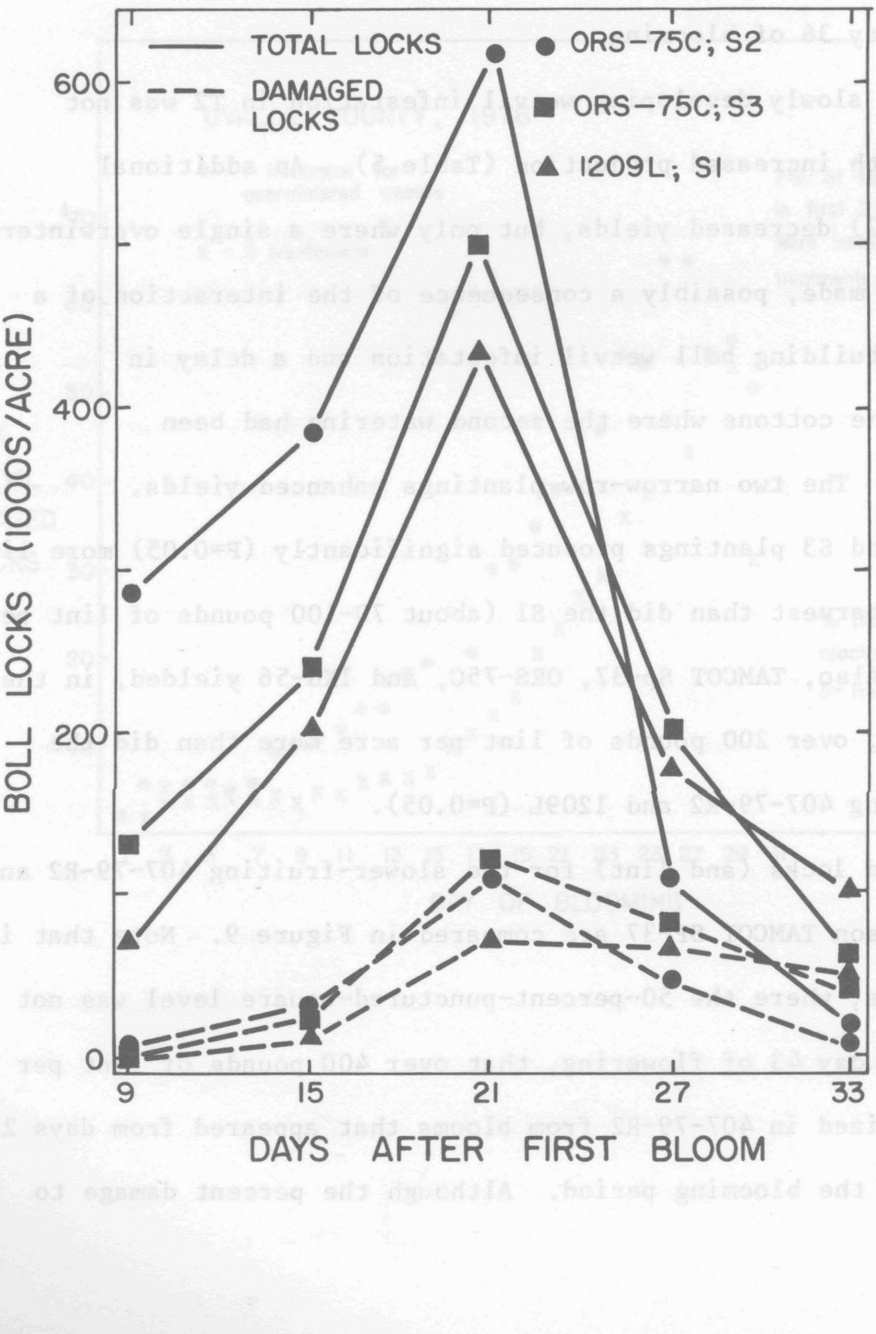
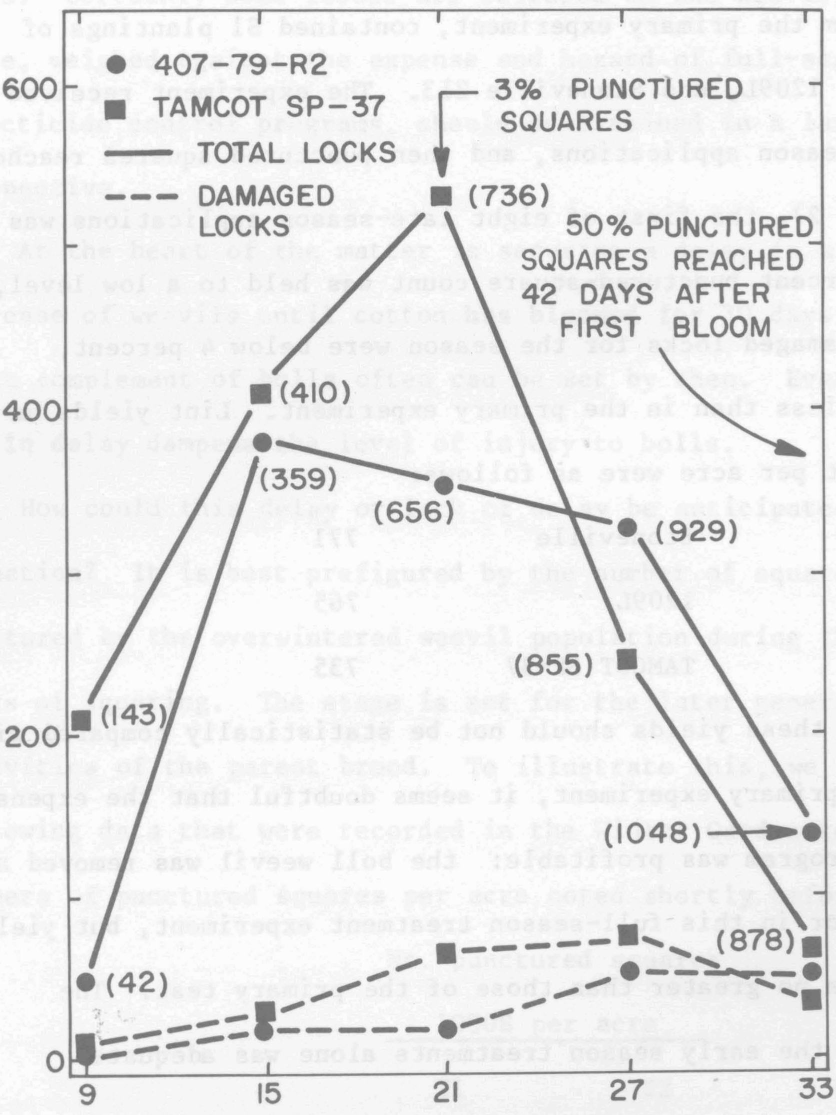


Figure 9. Accumulated lint in pounds per acre and numbers of locks that arose from different flowering periods in S2 plantings of two genotypes treated three times for overwintered weevils, Uvalde County, 1976 (T2 = three treatments).



locks increased in these later set locks, an important level of production was realized.

The slowly developing weevil infestation permitted all cottons, both quick and slow-fruiting, to establish relatively high yields. In fact, the slower-fruiting genotypes tended to yield more than the "fast" cottons such as TAMCOT SP-37. Perhaps the premature loss of leaves in this variety due to the plant disease caused the disparity.

Uvalde County, 1976; Full Season Treatment. This test, located about 200 yards from the primary experiment, contained S1 plantings of TAMCOT SP-37, 1209L, and Stoneville 213. The experiment received three early-season applications, and when punctured squares reached 30 percent (July 2), the first of eight late-season applications was made. The percent punctured-square count was held to a low level, and the percent-damaged locks for the season were below 4 percent, considerably less than in the primary experiment. Lint yields in pounds of lint per acre were as follows:

Stoneville	771
1209L	765
TAMCOT SP-37	735

Although these yields should not be statistically compared with those of the primary experiment, it seems doubtful that the expensive late-season program was profitable: the boll weevil was removed as a limiting factor in this full-season treatment experiment, but yields certainly were no greater than those of the primary test. The protection of the early season treatments alone was adequate.

"THE SHORT-SEASON EFFECT"

We use "short-season effect" to describe a situation in cotton production where, in the presence of the boll weevil, events are such that effective lint production is achieved without late-season insecticidal treatments. The effect is the result of a certain sequence of rapid fruiting by the cotton plant (rapid boll accumulation) that interfaces with a slowly developing weevil infestation; and from the dual role of the weevil toward squares and bolls. Certainly some losses are suffered to the weevil here but these, weighed against the expense and hazard of full-season insecticide control programs, should be examined in a larger perspective.

At the heart of the matter is securing a delay in a damaging increase of weevils until cotton has bloomed for 30 days or more. A large complement of bolls often can be set by then. Every additional day in delay dampens the level of injury to bolls.

How could this delay or lack of delay be anticipated in a given situation? It is best prefigured by the number of squares per acre punctured by the overwintered weevil population during the first 2 weeks of squaring. The stage is set for the later generations by the activities of the parent brood. To illustrate this, we submit the following data that were recorded in the Winter Garden tests on the numbers of punctured squares per acre noted shortly before blooming:

	No. punctured squares 1000S per acre	
	T1	T2
Frio County		
May 23	38.0	5.0

	No. punctured squares 1000S per acre	
	T1	T2
Uvalde 1975		
May 28	1.7	0.8
Uvalde 1976		
May 25	0	0
May 31	1.5	0

The presence of 5000 punctured squares per acre at the Frio County location in the T2, shortly before blooming, supplied ample seed for a vigorous, destructive first generation of weevils by day 20 of blooming (Figure 4). On the other hand, where counts of punctured squares were on the order of 1000-1500 per acre at the Uvalde site, the weevil explosion of summer-generation insects was importantly delayed, that is, achieving about 30 days of blooming, before weevils magnified to damaging levels, was realized only where the oviposition of overwintered weevils had been firmly reduced. One thousand punctured squares, when considered in the context of an acre of cotton, is a sparse population indeed and would scarcely be noticed; yet even here, in a matter of two generations, a large population of weevils developed. Even where the overwintered oviposition has been greatly curtailed, one can expect only about 30 to 40 days of blooming before the crop is overrun by the weevil.

But, as it happens, a period of 30 to 40 days seems to be an ample period to realize what we consider to be high yields, depending of course on the cotton genotype. This is true because of the duality of the weevil towards squares and bolls. Although the weevil is a serious threat to squares, it is much less so to bolls, even though the numbers infesting cotton at the time of boll maturation are commonly much greater than the population attacking cotton during the first several weeks of squaring. Daily, as a boll grows older before weevils attain large numbers, its chances for escaping lock injury are increased. It follows, then, that cotton that accumulate bolls more quickly in the framework of the fruiting sequence are advantaged.

Flowers in S2 plantings of TAMCOT SP-37 produced during the first 21 days of blooming at Uvalde during 1975-1976 gave rise to bolls that yielded over 700 pounds of lint per acre, and we did not regard the lock injury to these as severe. Narrow-row planting, S2 and S3 in all cottons, shored up escape; the S2 and S3 plantings further increased the accumulation of bolls earlier in the fruiting sequence.

Much has been written about the ability of the cotton plant to compensate for fruit loss. While this certainly may be the case, this compensation often cannot be appreciated unless a multi-application insecticidal program is practiced to ensure the benefits of that compensation. For example, cotton may have the potential to recover from a damaging cotton fleahopper infestation, but the realistic expression of this recovery may be lost to infestations of later summer-generation boll weevils. Loss of early fruit forms could alter the age structure of the boll complement such that it is made up of bolls of insufficient age to escape major lock injury from weevils.

Escaping the boll weevil in the system we have described is obviously highly probable, but what of those seasons in which, for some reason, boll set has not occurred as rapidly as one might wish? Perhaps a late-season treatment program with insecticides might be wise, but how could this judgement be made?

We believe a conservative estimate (or underestimate) of the extent to which cotton is reasonably safe from weevils can be made by a determination of the number of bolls per acre that are set that are 10 days or older by the time the weevil punctured-square count climbs to the 50-percent level. Recent work by scientists at Texas A&M University has shown that this can easily be done by boll-diameter measurement. These findings will appear in a later paper.

To Frederick Mally and other early-century entomologists, successful husbandry of cotton production in the face of the boll weevil reality was the consequence of a chance sequence of events that was, by and large, beyond anyone's direction. That is hardly the case today. Much of the uncertainty and gaming-table aspect of Mally's day have given way to experience, understanding, and technology. Cotton has moved from the high-rainfall areas of East Texas (those reaches that once allowed the pest to assert itself so well) to the west and to the upland prairies, where rainfall is less and the ecological fences more confining.

Great acreages are planted where the weevil is denied much pest status simply because it is deprived of available place to overwinter. Where successful overwintering can occur, the magnitude of this often is limited by harvesting practice--harvest-aid chemicals, machine harvest and community stalk destruction. Limited use of insecticides applied around the time of first squares has been successful in delaying injurious numbers of summer-generation weevils. Various short-season cotton varieties are widely planted by growers; full-season irrigation is no longer commonly followed, and nitrogen amounts are applied in reduced quantities.

REFERENCES CITED

Bennett, R. L. 1908. A method of breeding early cotton to escape boll weevil damage. USDA Farmers Bull. 314. 28pp.

Cook, O. F. 1923. Boll weevil cotton in Texas. USDA Bull. 1153 . 20pp.

Ewing, E. C. 1918. A study of certain environmental factors and varietal differences influencing the fruiting of cotton. Miss. Agric. Exp. Stn. Tech. Bull. 8. 93pp.

Heilman, M. D., M. J. Lukefahr, L. N. Namken and J. W. Norman. 1977. Field evaluation of a short-season production system in Lower Rio Grande Valley of Texas. Proc. of Beltwide Cotton Production Research Conferences. pp. 80-83.

Namken, L. N. and N. D. Heilman. 1973. Determinate cotton cultivars for more efficient cotton production in the Lower Rio Grande Valley. Agric. J. 65: 953-6.

Sprott, J., Ronald D. Lacewell, G. A. Niles, J. K. Walker, and J. R. Gannaway. 1976. Agronomic, economic, energy and environmental implications of short-season narrow-row cotton production. Tex. Agric. Exp. Stn. MP-1250C. 23pp.

Verhalen, L. M., R. Mamaghani, W. C. Morrison, and R. W. McNew. 1975. Effect of blooming date on boll retention and fiber properties in cotton. Crop Sci. 15: 47-52.

Walker, J. K. and G. A. Niles. 1971. Population dynamics of the boll weevil and modified cotton types. Tex. Agric. Exp. Stn. Bull. 1109. 14pp.

Walker, J. K., G. A. Niles, J. R. Gannaway, R. D. Bradshaw and R. E. Glodt. 1976. Narrow-row planting of cotton genotypes and boll weevil damage. J. Econ. Entomol. 69: 249-53.

Walker, J. K., J. R. Gunnaway and G. A. Niles. 1977. Age distribution of cotton bolls and damage from the boll weevil. Ibid. 70: 5-8.

Ware, J. O. 1925. Cotton variety experiments. Ark. Agric. Exp. Stn. Bull. 1970. 27pp.

The Texas Agricultural Experiment Station, Neville P. Clarke, Director, The Texas A&M University System, College Station, Texas
2M—8-80