B-1054 August 1966

DIAPAUSE BOLL WEEVIL CONTROL:
a comparison of two methods

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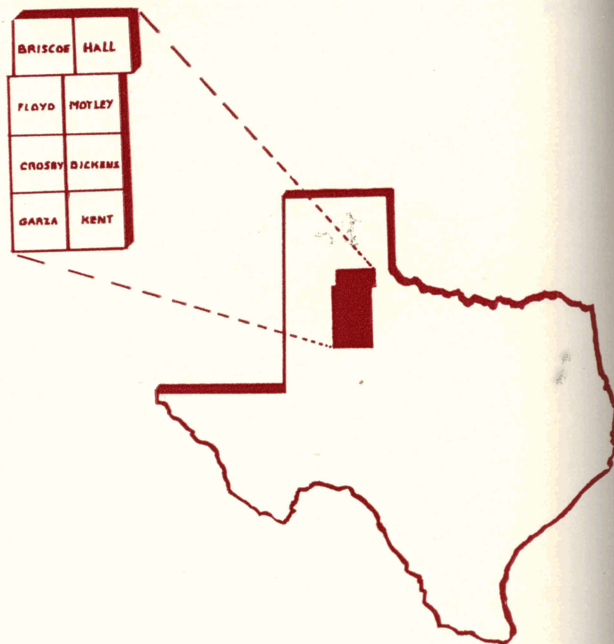

THE EIGHT-COUNTY CONTROL AREA

Summary

Insecticidal control of fall populations of boll weevils in the High and Rolling Plains during 1964 and 1965 made it possible to compare the relative effectiveness of two types of diapause control programs. Both programs dealt with reducing the overwintering boll weevil population.

The 1964 program utilized six applications of malathion in an attempt to kill the potential overwintering adults during the feeding period after they had emerged from infested squares or bolls but before they had left the cotton fields for nearby overwintering sites. This program produced a 90 percent reduction in the fall population. However, a great many weevils survived to infest the 1965 crop.

The 1965 program combined control of the last reproductive generation of boll weevils in September with control of potential diapausing survivors in October and November.

The 1965 program proved greatly superior to the 1964 program. The adult boll weevil population was reduced approximately 99 percent, and several times fewer weevils survived to enter hibernation than following the 1964 program.

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DIAPAUSE BOLL WEEVIL CONTROL: a comparison of two methods

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THE WINTER CLIMATE of Temperate Zones offers an extreme hazard to many insects. The boll weevil, *Anthonomus grandis* Boh., minimizes this hazard by overwintering in a state of dormancy, called diapause. Although the diapause phenomenon has been recognized in insects since 1869 (Duclaux, 1869) it was not known for the boll weevil until 90 years later when Brazzel and Newsom (1959) discovered that this species overwinters as a diapausing adult. The diapause syndrome of adult boll weevils is characterized by the cessation of gametogensis and atrophy of gonads, increase in fat content, decrease in water content and decrease in respiratory rate (Brazzel and Newsom, 1959).

The diapausing adults typically occur in the fall population. They apparently feed for a few days after emerging from infested squares or bolls, after which they migrate from the cotton fields to nearby woody or brushy areas in search of suitable overwintering sites. Once the insects find a suitable site they settle into the leaf litter near the soil surface where they become sedentary. The weevils apparently remain in these sites until the following spring. Diapause is terminated at this time and the weevils leave the woody areas to enter cotton fields. These weevils become reproductive and produce the first generation of the new season (Brazzel and Newsom, 1959; Brazzel *et al.*, 1961; Lloyd *et al.*, 1964; Mitchell and Mistric, 1965).

Not all adults present during the fall enter diapause. Many continue to reproduce, thereby increasing the population. The final diapause status of the boll weevil adult apparently depends on the environmental conditions, mainly day length and temperature, experienced by the individual insect. If the environmental conditions are appropriate for diapause after the egg is laid, the subsequent adult will be of the diapause type; if these conditions are inappropriate the insect will not diapause but will produce yet another generation (Earle and Newsom, 1964; Sterling and Adkisson, 1966).

The overwintering period has been recognized as a potential "weak link" in the seasonal cycle of the boll weevil which might be exploited for purposes of controlling the pest. As early as 1895, Townsend recommended that stalks be burned immediately after harvest in an attempt to destroy food and breeding sites of late fall populations. Malley (1901), who was among the first to make recommendations for boll weevil control in Texas, advocated a cultural control program involving stalk destruction and plowing in

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the fall to reduce overwintering populations. However, many of these early efforts did not meet with great success. This probably was because substantial numbers of diapausing adults developed in the fields during the harvest period before the stalk destruction programs could be initiated (Brazzel and Hightower, 1960).

To overcome this difficulty, Brazzel (1959) conceived the idea of reducing diapausing boll weevil populations by repeated applications of methyl parathion at 10- to 14-day intervals during the harvest season. This method of reducing overwintering populations, termed "diapause boll weevil control," has been tested by several laboratories (Brazzel *et al.*, 1961; Lloyd *et al.*, 1964; Cleveland and Smith, 1964; Smith *et al.*, 1965). In each experiment, the potential overwintering boll weevil population was reduced, but in no case was eradication achieved.

The boll weevil was first reported in the High Plains of Texas in 1936 (Owen, personal communications). However, infestations great enough to produce substantial crop damage did not appear until the early part of this decade. Weevil damage in the High Plains in 1963 and 1964 caused much concern to area cotton producers. They requested assistance from Texas A&M University, Plant Pest Control and Entomology Research Divisions, USDA and the Texas Department of Agriculture in an attempt to stop the westward migration of the boll weevil. A diapause boll weevil control program was recommended as offering the best and most economical means for accomplishing this task.

Subsequently, the first diapause control program in the High Plains was initiated in late September 1964. As will be shown later, an improved control program was developed during 1965. Thus, the results obtained in the High Plains afford an opportunity to compare the effectiveness of two types of diapause boll weevil control programs.

PLAN OF ATTACK FOR 1964 PROGRAM

Very little was known in 1964 concerning boll weevil behavior in response to the environment of the High Plains. Because of this, a fall control program similar to the one tested by Brazzel (1961) in Presidio was planned for the High Plains. This program was based on the premise by Brazzel (1961) that "an insecticide program of two to four applications applied immediately before and during the harvest season, followed by destruction of food and breeding sites by frost, chemical or mechanical means, will materially reduce and possibly eradicate the overwintering boll weevil populations." This type of program was designed to kill diapausing adults during the feeding period after they had emerged from infested squares or bolls but before they left cotton fields for nearby woody or brushy areas for winter hibernation.

Accordingly, a diapause control program utilizing four applications of malathion was planned. This was to be applied by the low volume method at the rate of 12 fluid ounces of 95 percent technical insecticide per acre. The insecticide was applied by airplanes flying at an altitude of approximately 20 feet and at swath-width spacings of 100 feet. However, after the first two applications, the rate was increased to 16 fluid ounces per acre by decreasing the swath width to 75 feet. This adjustment was made because the tremendous size of the boll weevil population demanded an extremely high level of control.

Treatment was initiated September 16, 1964, with applications made at intervals of 10 to 14 days. At the end of the fourth treatment, it was evident that most producers were not going to terminate their crops with desiccants or defoliants. Also, at this time the weather was quite warm, furnishing no indication of an immediate killing frost which would terminate the crop, thus rendering it unsuitable for further feeding and reproduction by the boll weevil. In addition, boll weevil numbers still were high. For these reasons, two additional applications of malathion were made but because of limited funds only the areas having the greatest infestations were treated.

Briscoe, Hall, Floyd, Motley, Crosby, Dickens, Garza and Kent Counties were included in the control zone. All the infested cotton acreage, almost 300,000 acres, were sprayed at the beginning of the diapause control program. Total acreage treated during the 1964 and 1965 fall programs is reported in Table 1. More specific detail previously was reported by Adkisson *et al.*, 1965.

TABLE 1. TOTAL NUMBER OF ACRES TREATED PER APPLICATION DURING THE 1964 AND 1965 DIAPAUSE BOLL WEEVIL CONTROL PROGRAMS IN THE HIGH AND ROLLING PLAINS

Application number	Acres treated 1964	Acres treated 1965
1	294,845	247,935
2	296,147	251,086
3	242,526	253,176
4	195,992	252,664
5	88,620	238,242
6	18,533	202,771
7	None	63,350
Total	1,136,663	1,509,224

RESULTS OF THE 1964 PROGRAM

A number of fields were monitored in the center of area where the greatest infestation occurred so that the efficiency of the insecticidal treatments could be checked. All monitored fields were in Dickens County. The data were collected by examining all squares and bolls on plants growing on 150 to 300 feet of randomly selected rows. The number of adult weevils were counted, collected and finally dissected to determine their diapause status. Untreated fields were used as checks. A detailed report of these records was made by Adkisson *et al.* (1965).

Typical results produced by the 1964 program are shown in Table 2. Two of the three fields were treated with malathion. The untreated field used for purposes of comparison was adjacent to both treated fields. Results show that, following the fourth malathion treatment, the boll weevil population had been reduced to an estimated 211 weevils per acre on one treated farm (Haney's) but was quite high, an estimated 2,574 adults per acre, on the other treated farm (Ragland's). Of course, the populations on the treated farms were considerably smaller than on the untreated acreage.

The first killing frost occurred almost a month after the fourth malathion treatment on October 22. During this time the population on the Haney farm increased greatly, and just before frost an estimated 1,056 adult boll weevils per acre were present. On the Ragland farm the population was reduced from an estimated 2,574 adults per acre on October 21 to 1,848 on November 11. This number of adults survived in the two fields even though they were treated with six applications of malathion. Population trends from October 24 to November 11 showed the importance of treating undefoliated fields until frost. One can only imagine what the population increase would have been if treatment of these fields had been terminated with the fourth application on October 22. There is little doubt that if the fifth and sixth applications had not been made, the reductions produced by the first four treatments would have been largely negated. These results show that, under the environmental conditions and present management practices in the High Plains, insecticidal treatments of a diapause control program should be continued until frost. It appears likely that six or more applications of insecticide will be required during most falls, unless the first killing frost occurs at a very early date.

The overall effect of the six malathion treatments, as measured by the seasonal means, was to reduce the potential overwintering populations which developed in treated fields by more than 90 percent (Table 2). Although this was a substantial reduction, there was still an average of more than 200 potential

TABLE 2. A COMPARISON OF THE NUMBERS OF POTENTIAL OVERWINTERING BOLL WEEVILS IN TREATED AND UNTREATED FIELDS SHOWING THE EFFECTIVENESS OF THE 1964 CONTROL PROGRAM. THE TREATED FIELDS EACH RECEIVED SIX APPLICATIONS OF MALATHION DURING THE PROGRAM (ADKISSON, ET AL., 1965)

Date		Estimated number adults per acre	Percent diapause	Estimated number potential overwintering adults per acre	Percent reduction over adjacent untreated field
		Untreated farm			
October	16	5,800	40	2,320	
	21	9,108	40	3,643	
	24	18,480	80	14,784	
November	6	21,120	29	6,125	
	12	6,600	48	3,168	
Mean		12,221	47	6,008	
		Treated farm No. 1 (Haney) [1]			
October	16	528	12	63	97
	21	0	0	0	100
	24	211	9 (est.)	19	99+
November	6	5,808	5	290	95
	11	1,056	37	391	88
Mean		1,521	13	153	96
		Treated farm No. 2 (Ragland) [1]			
October	16	528	12	63	97
	21	2,574	10	257	93
	24	1,372	4	55	99+
November	6	3,432	18	618	90
	11	1,848	13	240	92
Mean		1,951	11	247	94

[1]The treatment schedules for these fields were as follows: first application, 12 fluid ounces per acre of malathion, September 17-22; second application, 12 fluid ounces per acre of malathion, October 1; third application, October 13; fourth application, October 22; fifth application, November 11; and sixth application, November 20. The last four applications of malathion were made at the 16-fluid-ounce-per-acre rate.

overwintering adult boll weevils per acre which survived in treated fields.

Examinations of leaf litter taken from woody and brushy land suitable for hibernation by the boll weevil were made in January, 1965. Samples were taken across the control zone. A summary of these data, reported in Table 3, confirm the population records made in treated cotton fields. The hibernating boll weevil population averaged an estimated 281 adults per acre of hibernation quarters, a reduction of 89.4 percent over the population of the previous year when no fall control was practiced, and confirmed the field records presented in Table 2.

1965 POPULATION INCREASES BY 1964 SURVIVORS

Surveys were initiated in June 1965 to study the rate of population increase following the 1964 program. The surveys were begun in June as the seedling cotton emerged to a stand. This research was confined to Dickens County, the area of heaviest infestation; this also was the area which had received the six malathion treatments in the fall of 1964.

Nine fields were selected for surveys. Four fields were irrigated and five were dryland. Five fields were treated by the producers in July and August for boll weevil control while the other four were left untreated. For the most part, the treated fields received malathion applied by the low volume technique at rates of 8 to 12 fluid ounces per acre per application. These fields were treated at intervals of approximately 6 to 7 days from July 10 to the first week of September. The nine fields were located so as to be representative of the entire area and so that the population estimates might be made on a county basis.

Records were made at weekly intervals during the season by making whole plant examinations at six randomly selected locations in each field. Fifty feet of row was examined at each location to provide a total sample of 300 feet of row per field. The number of adult boll weevils on the 300 feet of row was recorded and the data converted to form estimates of number of adults per acre.

TABLE 3. ESTIMATED NUMBERS OF HIBERNATING BOLL WEEVILS PER ACRE IN THE LEAF LITTER OF WOOD AND BRUSH LAND IN THE CONTROL ZONE BEFORE AND AFTER THE DIAPAUSE CONTROL PROGRAM

Date of record		Estimated number of hibernating weevils per acre	Percent reduction produced by diapause control program[1]
Month	Year		
January	1964	2,650	
January	1965	281	89.4
January	1966	48	98.2

[1]Percent reductions in overwintering boll weevils were calculated for both 1965 and 1966 on the basis of the uncontrolled hibernating population of January, 1964.

TABLE 4. ESTIMATED SIZE OF THE BOLL WEEVIL POPULATION IN DICKENS COUNTY, TEXAS DURING 1965

Date inspected		Estimated number of adults: Per acre	Estimated number of adults: Dickens County
June	18	10[1]	529,460
	25	20[1]	1,058,920
July	2	5[1]	264,720
	9	34[1]	1,800,164
	16	15	794,190
	23	20	1,058,920
	30	0	0
August	6	20	1,058,920
	13	27	1,429,542
	18	207	10,959,822
	27	264	13,977,744
September	3	129	6,830,034
	10[2]	116	6,141,736
	15	495	26,408,270
	20	1,386	73,383,156
	28	710	37,591,660
October	8	248	13,130,608
	12	578	30,605,788
	18	339	17,948,694
	28	358	18,954,668
November	1	242	12,812,932
	8	22	1,164,812
	16	154	8,153,684
	21	158	8,365,468

[1]Overwintered weevils.
[2]First phase of diapause control program was initiated on September 7, 1965. Entire population after this time was under treatment with malathion.

Population records, summarized in Table 4, show that the average number of overwintering boll weevils surviving to infest seedling cotton in the spring of 1965 ranged between 5 and 34 per acre. Overwintered weevils were present in the fields from June 18 to July 9. The first generation of boll weevils began to emerge during early July. After this, it was not possible to identify the collected weevils according to parent or generation number.

The boll weevil population during July and early August remained relatively stable, barely maintaining its numbers. There was no population increase attributable to the first (F_1) generation. The estimated numbers of adults per acre ranged from 0 to 27 during the period July 16 to August 13. The lack of increase by the boll weevil during this time probably was attributable to insecticidal treatment of the irrigated fields and to hot, dry weather, high soil temperatures and lack of shade in the dryland fields, since the cotton plants in these fields were still quite small in July. These conditions will cause high mortality in immature forms of the boll weevil in squares which fall on unshaded ground.

The population increased approximately 10-fold during the last half of August. For example, on August 13, the population was estimated at 27 adults per acre while on August 27, the average was 264 adults per acre. This increase probably was due to the emergence of another generation of boll weevils. It should be noted that this increase occurred even though five of the nine surveyed fields were being regularly treated with insecticides for weevil control.

The boll weevil population made an additional increase of approximately 5-fold from late August to late September. For example, there was an average of 264 adults per acre in the fields on August 27. By September 20, the number had increased to an average of 1,386 adults per acre. This increase occurred even though all the surveyed fields were treated with three applications of low volume malathion at the 16-fluid-ounce-per-acre rate at 5-day intervals between September 7 and September 20, 1965.

These results show the tremendous reproductive capacity of the boll weevil. During the growing season the weevils increased to relatively great numbers, even though the overwintering population was quite small. Much of this increase occurred despite regularly scheduled insecticidal treatments which have been found capable of killing from 80 to more than 90 percent of the adults in the fields at time of treatment (Adkisson *et al.,* 1965).

Estimates also were made of the total numbers of adult boll weevils in Dickens County during the 1965 season (Table 4). The estimates, although gross, furnish some indication of the tremendous numbers of boll weevils that might be present in a relatively small area. The population increased during a 3-month period from an estimated 529,460 adults on June 18 in seedling cotton to 73,383,156 individuals by September 20. Such magnitude shows the extremely high efficiency that must be obtained in any type of boll weevil suppression or eradication program. A diapause control program which killed approximately 90 percent of the adult boll weevils in Dickens County during the fall of 1964 still left a great number of survivors to infest the county in 1965.

These results clearly show that although the 90 percent population reduction obtained in 1964 might be considered excellent, this level of control was not sufficient to prevent crop damage during the subsequent growing season. However, the 1964 diapause control program offered an excellent adjunct to the regular control practices conducted by producers. It removed much of the normal population pressure and was responsible for the small populations that were evident until late in the season. It is obvious, however, that the 1964 program fell far short of eradication; and, in fact, the population suppression was not sufficient to prevent some migration in September.

In view of these results, research was expanded in an attempt to develop a more efficient control program for 1965.

BASIS FOR 1965 PROGRAM

Knipling (1963) discussed several approaches for reducing diapausing boll weevil populations. He advanced the hypothesis that a program aimed at killing the last reproductive generation of weevils would be considerably more effective than schemes designed to kill diapausing adults before they leave cotton fields for overwintering sites. In 1964, experiments designed to provide the information needed to implement this approach were initiated.

Sterling and Adkisson (1966) studied environmental factors causing diapause of the boll weevil in laboratory and field experiments. They developed a technique, using adult boll weevils reared from infested squares, for determining more exactly the time when diapause is first initiated under fields conditions. Sterling and Adkisson showed that on the High Plains in 1964 the first potential overwintering boll weevils of the season developed from eggs that were laid from mid-August to early September. The last reproductive generation, for the most part, occurred in September. Females present in September apparently produced the majority of the eggs which gave rise to the diapausing, or overwintering adults.

These studies were continued in 1965. The incidence of diapause was studied in field-collected adults and in weevils reared from infested squares and bolls. The adults were taken at random by hand-picking weevils off infested plants in Dickens County. Also, weevil-infested squares and bolls were collected weekly from fields near Spur during the summer and fall. These were held in an open insectary until the adult weevils emerged. These adults were fed for 20 days, then dissected and examined for diapause.

Results, summarized in Figure 1, closely paralleled those reported for 1964 by Sterling and Adkisson (1966). These data again show the advantages of rearing boll weevils from squares and bolls for determining the seasonal incidence of diapause. A number of the square- and boll-reared adults that emerged in August attained diapause. However, the combined data indicated that September probably was the most important month for the development of the diapause broods. Most eggs laid in September developed into adults of the diapause type.

PLAN OF ATTACK FOR 1965 PROGRAM

The above studies provided the basis for changing the diapause control program in 1965. The plan of attack was simple. A two-phase program was designed along the lines suggested by Knipling (1963). Phase 1 utilized three applications of malathion delivered at 5-day intervals during early and mid-September. The objective of this phase was to break the reproductive cycle of the boll weevil, thereby preventing the females from laying the eggs that eventually develop into diapausing adults. Calculations indicated that if the insecticide killed 90 percent of the females, the size of the overwintering brood also would be reduced by 90 percent, even if no further control was practiced. However, phase 2 was designed to deal with this problem. Four applications of malathion were made at 10- to 14-day intervals through October and November until frost. The objective of these applications was to kill any adult boll weevils that might have escaped the Phase 1 treatment or that might have developed from eggs laid in late August or the first few days of September before the insecticidal applications were initiated.

RESULTS OF 1965 TWO-PHASE PROGRAM

The 1965 control program was conducted as planned under the supervision of the Plant Pest Control Division, USDA. Seven applications of malathion were applied by the low volume technique at a dosage of 16 fluid ounces of 95 percent technical malathion per acre per application. The insecticide was applied by airplane at swath widths of 100 feet. The acreages treated per application in the eight-county area during 1965 are given in Table 1.

The first application of Phase 1 was initiated September 7, 1965. The next two applications were delivered on schedule, 5 to 6 days apart. Seventeen fields which were relatively heavily infested with boll weevils were selected at random across the entire control zone for monitoring. These fields were checked at weekly intervals. All the plants on 50 feet of two randomly selected rows were examined and the number of weevils recorded. Weevils were collected and examined the same day to determine their diapause condition. In addition, the number of egg punctures and immature weevils in the squares and bolls of the plants on the two samples were recorded.

The effectiveness of the Phase 1 treatments in breaking the reproductive cycle of the boll weevil is shown in Figure 2. These data furnish a comparison of the estimated number of immature weevils that were present in fields which had been treated during the summer months by the producers as opposed to fields which were not treated during this period. All of these fields were treated with malathion during the diapause control program.

The fields which had not been treated during the summer harbored more than 6,000 immature weevils per acre on September 3, 1965. Egg production in these fields was stabilized by the first malathion treatments made during the 5-day period beginning September 7. Unfortunately, widespread and heavy rains occurred during the period of the second appli-

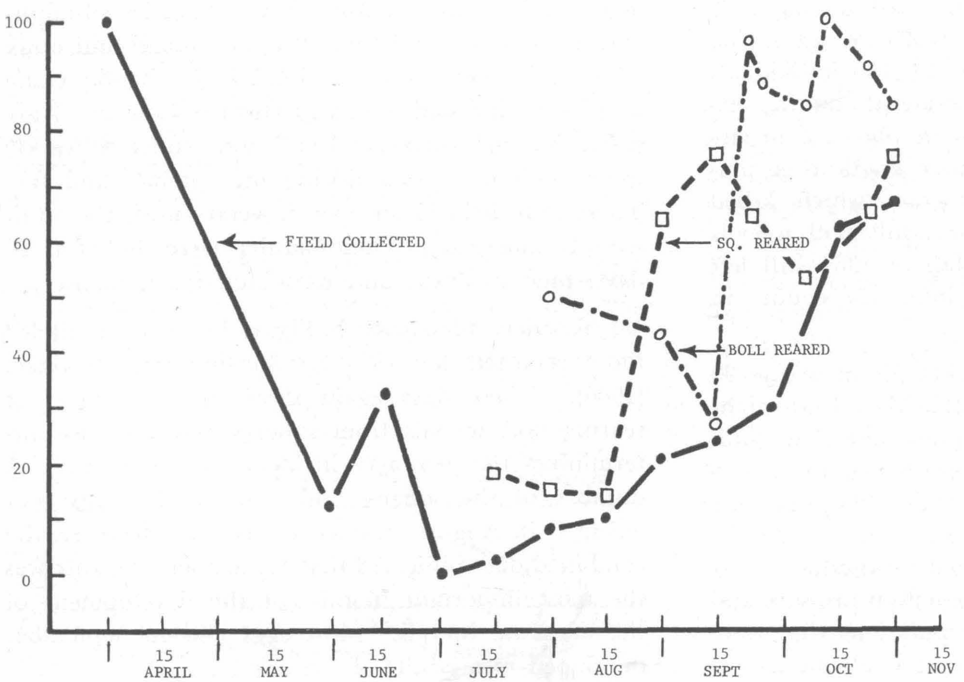

Figure 1. Seasonal incidence of diapause in field-collected adult boll weevils compared to that in square- and boll-reared adults. Dates indicate days on which field adults were collected and on which square- and boll-reared adults emerged. Field-collected adults were examined on date of collection, while square- and boll-reared adults were fed small bolls for 20 days before being examined for diapause.

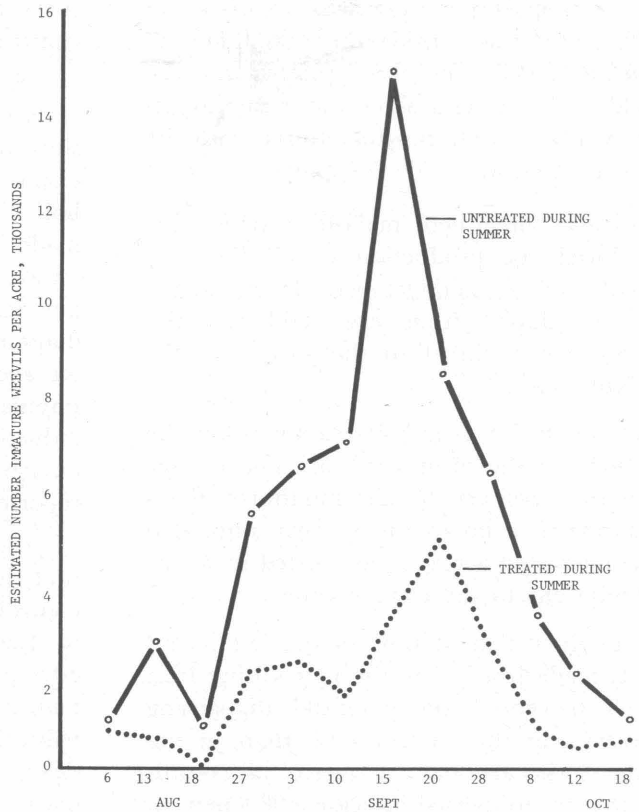

Figure 2. Estimated numbers of immature boll weevils per acre in fields treated during the growing season compared to those in untreated fields, Dickens County, Texas, 1965. All fields were treated with malathion during the diapause control program in the fall of 1965.

cation during mid-September, and egg production in these fields soared, reaching a peak of almost 15,000 per acre on September 15. Population trends in Figure 2 show that these rains destroyed the effectiveness of the second malathion application and greatly reduced the effectiveness of the Phase 1 program.

Fields treated by producers during the summer had many times fewer immature boll weevils per acre than did untreated fields. For example, on September 3, the immature population in these fields averaged slightly more than 2,000 immature weevils per acre. This compares to more than 6,000 per acre in the untreated fields. The first malathion application reduced egg production in these fields (Figure 2). As indicated by the record made September 10, egg production in the treated fields, as in the untreated fields, soared during the rainy period of mid-September. This increase, however, was not nearly so great as in the untreated fields as peak numbers of approximately

TABLE 5. ESTIMATED PERCENTAGE REDUCTION IN THE POTENTIAL OVERWINTERING POPULATION OF ADULT BOLL WEEVILS IN THE HIGH PLAINS OF TEXAS PRODUCED BY THE FALL APPLICATIONS OF MALATHION, 1965

	Treated acreage			Untreated control			
Date	Estimated number of adults per acre	Percent diapause	Estimated number of hibernating adults	Estimated number of adults per acre	Percent diapause	Estimated number of hibernating adults	Estimated percent reduction
September 10				2,350			
15	519	14.6	76	6,650			
20	1,302	12.5	163	14,550			
28	893	23.7	212	6,950			
October 8	478	8.0	38	11,000	50.0	5,500	99.3
12				7,050	61.0	4,301	
18	567	53.6	304	15,550	60.0	9,330	96.7
28	334	37.5	125	11,650	40.0	4,660	97.3
November 1	204	75.0	153	12,200	58.0	7,076	97.8
8	176	50.0	88	6,750	75.0	5,063	98.3
16	209	0.0	0	5,150	75.0[1]	3,863	100.0
21	211	23.2	49	6,350	75.0[1]	4,763	99.0
Mean	489	29.8	121	8,850	61.7	5,570	98.3

[1]Percentages of diapausing weevils for these two dates were estimated as being the same as in the collection of November 8.

5,000 immature weevils per acre were reached on September 20. This was considerably less than the 15,000 immature weevils per acre reported for the untreated fields. These data show the great importance of the regular season control efforts made by producers during August.

The third and subsequent malathion treatments eventually reduced egg production in all fields to extremely small levels by mid-October. However, the adults which developed from eggs laid in mid-September presented a threat to the success of the program in November.

Effects of the Phase 1 and 2 treatments on the adult populations are shown in Table 5. The average numbers of weevils per acre in the monitored fields of the control zone are compared to a nearby untreated acreage. The untreated acreage was located in Stonewall County adjacent to the control zone.

These data show that at time of the last record (November 21) made just before the first killing frost there were 99 percent fewer potential diapausing adult boll weevils in the control zone than in untreated acreage. The seasonal averages of all records made during the control period indicate a 98.3 percent overall reduction in the population. Thus, it might be concluded that the new two-phase diapause control program was as efficient as the hypothetical model of Knipling's (1963) which predicted a 99 percent reduction.

A comparison is made in Table 6 of the estimated average number of adult boll weevils per acre in Dickens County during the 1964 and 1965 diapause control programs. These records show that there were 92 percent fewer adult weevils per acre in Dickens County at the end of the 1965 program than at a similar time following the 1964 program. It was calculated that the two-phase diapause control program should be approximately 90 percent more effective than the 1964 program. Again, field performance confirmed the hypothesis.

TABLE 6. A COMPARISON OF THE ADULT BOLL WEEVIL POPULATIONS IN DICKENS COUNTY IN 1964 AND 1965 SHOWING THE IMPROVED EFFICIENCY OF THE TWO-PHASE PROGRAM OF 1965

Date	1965 Estimated number of adults per acre	1964 Estimated number of adults per acre	Percent reduction
Oct. 12	578	3,280	82
18	339	2,208	85
28	358	4,277	92
Nov. 1	242	594	59
6	22	6,178	99+
16	154	2,323	93
21	158		
Mean	264	3,143	92

Examinations were made for adult boll weevils in January 1966 in leaf litter from known hibernation sites across the control zone (Table 3). The 1966 examinations were made only at locations in which boll weevils had been found during similar studies made in January 1965. These results indicated that an average of 48 potential over-wintering boll weevils per acre of hibernation site had survived the 1965 diapause control program. This number represented an average reduction of 98.2 percent in the 1965 population when compared to 1964. The percentage reduction of weevils in hibernation sites was almost exactly the same as obtained in the field records reported in Table 5.

These records provide almost conclusive proof that the two-phase program of 1965, which combined control of the last reproductive generation with that of the diapausing broods, was considerably more effective than the 1964 program. The latter program had as its objective the killing of the potential overwintering adults during the feeding period after they emerge from infested squares or bolls but before they leave cotton fields in search of suitable overwintering sites.

CONCLUSIONS

The population trends presented in Table 4 and Figure 2 show the advantage of initiating the first insecticidal treatments of the diapause control program in the first week of September. The boll weevil population increased approximately 10-fold from September 3 to 20. This increase occurred even though the population was subjected to three malathion treatments between September 6 and 20. There is no way to estimate the size the 1965 population might have reached in September if the malathion treatments had been delayed to September 16, or later, as they were in 1964. There is no doubt that the population increase in September, 1965 would have been much greater if there had been no treatment, and perhaps, the population may have even increased to the same proportions as was present in the uncontrolled population in September, 1964 before the diapause control program was initiated.

One other factor favoring the earlier treatment date of 1965 is the pattern of migration of the boll weevil populations in the High and Rolling Plains. The first evidence of migration from field to field in the control zone was detected during early September. The first 1965 malathion treatment made during the 5-day period of September 7 to 12 apparently coincided with the beginning of migration. The first three malathion treatments made in September undoubtedly

TABLE 7. COMPARATIVE EFFECTIVENESS OF THE 1964 AND 1965 DIAPAUSE CONTROL PROGRAMS IN REDUCING THE SIZE OF THE POTENTIAL OVERWINTERING BOLL WEEVIL POPULATIONS

	Treated acreage			Untreated acreage			
Year	Estimated number of adults per acre	Average percent in diapause	Estimated number of hibernating adults per acre	Estimated number of adults per acre	Average percent in diapause	Estimated number of hibernating adults per acre	percent reduction
1964	2,323	25	363	6,600	48	3,168	89
1965	211	23	49	6,350	75	4,763	99

prevented a relatively great and serious migration of the boll weevil to uninfested acreage to the west. This would have increased the size of the control zone considerably.

The combined results produced by the 1964 and 1965 programs are compared in Table 7. These data show that the overwintering population was reduced by approximately 90 percent in 1964 and 99 percent in 1965. In population suppression programs, the insects which survive are more important than those that are killed. There were nine times fewer insects surviving the two-phase program of 1965 than the conventional program of 1964. This means that for each 100 boll weevils which might have survived the winter if there had been no diapause control program, ten survived the conventional program of 1964, but only one survived the two-phase program of 1965.

The combined results obtained to date indicate that it will be extremely difficult, if not impossible, to reduce a boll weevil population by present diapause control procedures to such a small size that insecticidal control measures may be abandoned completely. It seems more likely that insecticidal control will have to be continued until other non-insecticidal control measures are developed for eliminating the last 1 percent of the population.

ACKNOWLEDGMENTS

This research was conducted in cooperation with the Entomology Research Division, USDA, under a memorandum of agreement 12-14-100-5607 (33). The aerial spraying operation was conducted under the supervision of the Plant Pest Control Division, USDA, with assistance from the Texas Department of Agriculture. Assistance of numerous personnel from these latter two agencies in obtaining insect records during the spraying operation and examination of hibernation sites also is gratefully acknowledged. Special thanks is due Bruce Hewlett and coworkers, Plant Pest Control Division, USDA, who furnished population records for the untreated acreage reported in Table 5.

The diapause control program over the eight-county area was organized and financially supported by the cotton producers of the area as represented by the Plains Cotton Growers, Incorporated, Lubbock.

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