No. 5

PINK BOLLWORM INFORMATION

COOPERATIVE RESEARCH ON THE PINK BOLLWORM AND RELATED COTTON INSECTS

ENTOMOLOGY RESEARCH CENTER
AGRICULTURAL RESEARCH SERVICE, U.S.D.A.
BROWNSVILLE, TEXAS

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P I N K B O L L W O R M I N F O R M A T I O N

NO. 5

Introduction: This report is now being prepared and distributed on an annual basis to give agricultural officials concerned with this cotton pest a picture of its staus and of the progress of the cooperative research program. Its distribution this year is timed to be of special benefit to members of the Pink Bollworm Technical Research Committee and the S-37 Regional Project on Pink Bollworm Control, which meet at Brownsville, Texas, on August 5 and 6, 1957. Previous issues of this series have appeared as follows: No. 1, May 26, 1954; No. 2, October 29, 1954; No. 3, May 15, 1955; and No. 4, May 15, 1956.

Cooperation and Financial Support: The overall cooperation of the various States, Oscar Johnston Cotton Foundation, and the U. S. Department of Agriculture on planning and conducting the research program during the past year has been excellent. On July 1, 1956, Mississippi's financial contribution was lost but U.S.D.A.'s increase for pink bollworm research was sufficient to absorb this loss. Alabama, Georgia, and the Oscar Johnston Cotton Foundation continued their contributions through June 30, 1957, on the same level as during the previous year. However, these funds, amounting to $45,000 made available through the U. S. Department of Agriculture, were no longer available after June 30, 1957. After September 1, 1957, Alabama will no longer furnish an entomologist (J. A. Griffin) and support at Brownsville. The U. S. Department of Agriculture is making every effort possible to replace on a temporary basis this loss of State and Oscar Johnston funds, in order to keep the research program on the same level for this present year as it was last year.

PLANT PEST CONTROL DIVISION
Pink Bollworm Control Program

(Prepared by Southern Region, Gulfport, Miss.)

I. Infestation

In the crop year 1956, the pink bollworm made little or no gain in infested area. The only new area discovered was Washington County, Arkansas, found infested for the first time involving five acres of cotton and the only producing field in the county.

The states of Arkansas and Louisiana showed spotted infestations in some of the western counties, ranging from a trace to very light. Oklahoma was generally infested in most counties, with pink bollworm populations ranging from very light to heavy. There was no commercial damage in these three states.

In Texas the infestations were general, ranging from heavy in the southern half of the state to very light in some of the eastern counties. The infestation in the Lubbock area was more general and heavier than ever before. Substantial infestations also developed for the first time in Childress, Motley, King, and Cottle Counties in western Texas.

Two counties of Arizona, Cochise and Graham, showed trace infestations and one county, Greenlee, ginning considerable cotton from New Mexico, showed substantial gin trash infestations. In New Mexico, severe infestations developed in Dona Ana and Lea Counties; light to threatening infestations in Luna, Roosevelt, and Hidalgo Counties.

Inspections of the 1956 crop are summarized below:

State	Number of counties in category[1/]					
	Negative	Very light	Light	Threatening	Severe	Heavy
Alabama	35	0	0	0	0	0
Arizona	4	2	0	1	0	0
Arkansas	38	9	5	0	0	0
California	8	0	0	0	0	0
Florida	4	0	0	0	0	0
Georgia	53	0	0	0	0	0
Louisiana	29	4	2	0	0	0
Mississippi	44	0	0	0	0	0
Missouri	6	0	0	0	0	0
New Mexico	0	0	2	1	2	0
Oklahoma	3	2	13	25	3	1
South Carolina	11	0	0	0	0	0
Tennessee	11	0	0	0	0	0
Texas	0	16	33	51	55	68

1/ See legend on map for further description of categories.

II. Damage from the Pink Bollworm in 1956

(a) Where Occurred

There was no damage in the infested areas of Louisiana, Arkansas, and Arizona, and only spotted light damage in some Oklahoma fields and in New Mexico. In Texas, late fruiting fields in south Texas and in the Brazos and Trinity River bottom lands were severely attacked and severe damage occurred where the cotton was not protected with heavy applications of insecticides. Damage up to 75 percent was noted in fields near El Paso. In west-central Texas, infestations were heavy enough to lower grades, and light commercial damage was common in Cottle, King, Childress, and Motley Counties. Late bolls in these counties were heavily damaged.

III. Stalk Destruction

Cultural controls which include stalk destruction are required by state regulations in 28 counties of Arkansas comprising a single zone, with January 31 as the deadline for completion; in 18 parishes of Louisiana, divided into three zones with required planting and stalk destruction dates; and in 106 counties of Texas, divided into seven separate zones, each with a specified planting and plow-up date.

Cooperation from farmers throughout all the cultural control zones was excellent, although many waited until the legal deadline date to comply. Some of these failed to do a satisfactory job because of unexpected weather toward the close of deadline dates. The effective stalk destruction programs undoubtedly have been a major factor in keeping infestations at an extremely low level in Arkansas and Louisiana and in keeping damage at a comparatively low level in South Texas.

To meet increased infestations in east Texas and infestations of damaging proportions in the upper Rio Grande Valley area of west Texas and New Mexico, two new cultural zones were established in 1956. Farmers and others are cooperating to make these new zones a success.

IV. Regulatory

(a) Because of the danger of accidental transportation of infested cotton bolls and products from heavily infested areas of Texas and Oklahoma into the noninfested states to the east, 15 traffic inspection stations were maintained cooperatively by the Branch and the states of Arkansas and Louisiana on all main roads entering these two states. From August 1956 through January 1957, approximately 2,000,000 vehicles were inspected and 2,400 interceptions made of contraband material. More than 700 living pink

bollworms were found in that part of the intercepted material examined. It is expected that this part of the program will be intensified during the coming season. Most of the living pink bollworms are carried by migratory cotton pickers and tourists carrying bolls or stalks.

(b) Other regulatory items

1. Some 200 mechanical cotton pickers were treated before leaving the regulated area.

2. Federal and state personnel supervised processing and treatment of some 5,000,000 bales of cotton and the associated products during the crop year, involving the use of approximately 75,000 permits to cover movement of the crop.

Over 30,000 bushels of edible okra were treated and certified for movement.

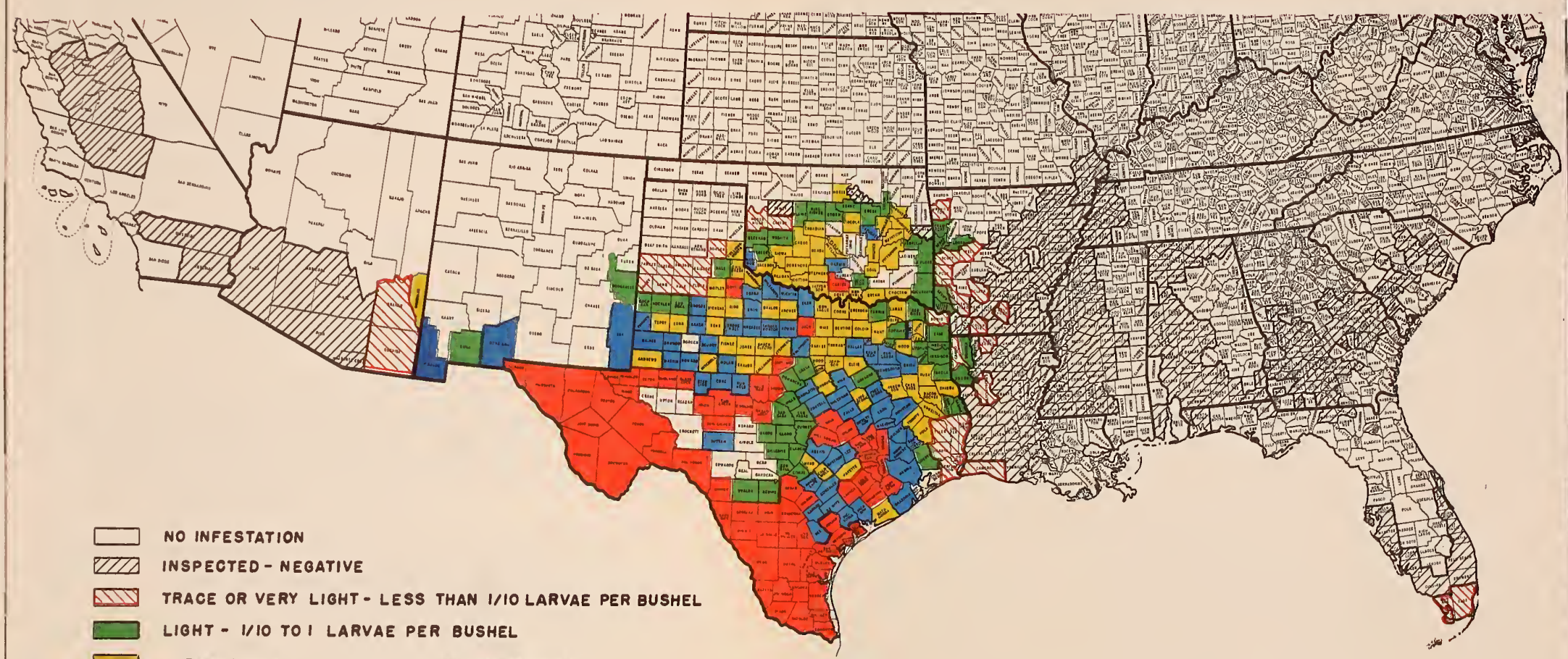
V. Outlook for 1957 Crop

The outlook is very satisfactory for the 1957 crop in Louisiana, Arkansas, Arizona, and New Mexico where infestations are expected to remain very light. In many areas of Texas and Oklahoma, continued buildup of infestations should be expected, particularly in the areas from San Angelo, Texas, north of Cottle County.

Substantial infestation may be expected to continue throughout south Texas. With continued alertness and the cooperation of all concerned, severe damage and spread to new areas can be prevented in the 1957 crop.

The attached map shows negative surveys and the estimated intensity of infestations by counties.

STATUS OF PINK BOLLWORM INFESTATIONS AS OF JAN. 1957



Based on gin trash samplings or equivalent

Prepared at Gulfport Miss. 7/1/67 LAB

ARKANSAS AGRICULTURAL EXPERIMENT STATION
(Charles Lincoln and T. F. Leigh)

The pink bollworm has now been recovered in 16 counties in western Arkansas, with all cotton producing counties adjacent to the Oklahoma state line found infested.

Pink bollworm hibernation studies were continued at Mt. Pleasant, Texas, during 1955-56 in cooperation with the Entomology Research Division. Five treatment-burial date and four crop-burial date combinations were included in addition to the standard treatments. Results have been reported by the Brownsville Entomology Research Center. This study has been continued in 1956-57.

Post harvest disposal of field residues by grazing was tested in southwest Arkansas. Grazing trials using saccharin to make cotton residues more attractive were inconclusive. Indications are that some increased feeding may be gained from use of saccharin. This investigation is being continued.

Timing of insecticide applications for control of the boll weevil and other cotton pests was investigated in southwest Arkansas in order to adjust present schedules to meet need for control of the pink bollworm, when necessary. The results of this investigation to date are reported in Arkansas Agricultural Experiment Station Bulletin 588, "Timing Insecticide Applications for Cotton Insect Control."

Varietal resistance to boll weevil in cotton varieties adapted to Arkansas growing conditions has been investigated. To date a degree of resistance has been found through escape, size of square, boll wall thickness, and through increased hardening of the inner carpel wall. This study is being continued with inclusion of wild types. If results justify, a correlated breeding program may be developed for pink bollworm-boll weevil resistance.

Infestation pin pointing was undertaken in the spring of 1956 through a review of all pink bollworm recoveries in gin trash. All previous gin trash recoveries in Arkansas were reviewed in cooperation with the USDA Plant Pest Control Branch and the Arkansas State Plant Board. Several grower names repeated in these recoveries. Bloom inspection undertaken in several of the suspected fields, resulting in location of one infested field. An insecticidal eradication program apparently was successful.

An individual grower trash survey system instituted in the fall of 1956 in which trash from each grower's cotton was taken separately resulted in location of field infestations in five counties.

THE TEXAS AGRICULTURAL EXPERIMENT STATION
and
THE LOUISIANA AGRICULTURAL EXPERIMENT STATION

1. Development of Stalk Cutter Shredders and Root Slicers:

Two experiments were conducted with stalk destruction machinery in the Brazos River Valley near College Station. In one experiment the following machines were tested: A - Modified Rotocycle; B - John Deere; C - Standard Rotocycle; D - Brady; E - AEX-6 (Modified); F - Case. Machines B, C, D and F were standard models as supplied by the manufacturer. The blades of machine A were modified by adding suction lifters to pick up ground trash. Machine E differed from the 1955 model in that it was reworked to lower the stripper-rolls.

Fewer pink bollworm larvae emerged from residues collected from machine treatments than from untreated checks. All machines were equally effective except machine B which gave considerably less kill.

In a second experiment additional measurements were made on AEX-6 and the standard Rotocycle. The following treatments were used:

A - Stripper unit alone (CK)
B - Standard Rotocycle
C - AEX-6
D - AEX-6 / Standard Rotocycle

Ground (storm loss), machine, and machine loss residue samples were taken and weighed. Moth emergence records indicate that approximately 26.9 percent of the total emergence of uncut samples was contained in ground (storm loss) residues. Considerable difficulty was experienced with the stripper unit of AEX-6 during the second test, and residue emergence records indicate that about 54.2 of the total emergence was contained in machine losses giving this machine an efficiency rating for this test of only 18.9 percent. Machine B had an indicated efficiency from moth emergence of 91.8 percent. Combining both machines in one operation increased the efficiency to 96.9 percent.

An attachment is needed for cutting cotton stalks below the surface of the soil to prevent regrowth and aid in land preparation. A power driven rotary disc type slicer appears promising.

M. G. Davenport, Agri. Engineer, TAES
W. J. Magee, Entomologist, TAES

2. Development of Sprayers:

The following treatments were used in an experiment in the Brazos Valley near College Station:

	Gal./Acre
A - 1 No. 6 nozzle every 40"	6
B - 3 No. 2 nozzles/row (drops)	6
C - 1 No. 2 nozzle every 20"	4
D - Pink bollworm check - endrin	
E - 1 No. 3 nozzle every 20"	6
F - 2 Field jet nozzles/40 ft.	11
G - 1 Boom-jet/40 ft.	11
H - Check	
I - 1 No. 2 nozzle every 40"	2

The initial pink bollworm infestation was in excess of 570 worms per acre at which time the experiment was started. Analyses of insect infestation records showed that treatment B had lower boll weevil infestations than treatments G or H, and that treatments A, B, C and I had lower bollworm square infestations than treatment H. There were no treatment differences in bollworm boll infestations or in pink bollworm bloom or boll infestations. Analyses of yield data showed that infestation differences were minor among insecticide treatments, because all treated plots yielded higher than untreated checks but did not differ from each other.

The broad jet nozzle assemblies such as the "Boom-jet" offer considerable promise. If these assemblies continue to perform well in future tests, it appears possible to replace spray booms without loss in insecticide effectiveness while making considerable saving in weight and expense.

W. J. Magee, Entomologist, TAES

Materials and parts have been secured to fabricate a self-propelled high clearance sprayer. This unit is to be designed to negotiate irrigated fields if possible and shall be constructed to evaluate those features which simplify construction and increase pay load without loss in effective plant coverage. In addition the machine for the Entomology Department described in the 1955 report has been reworked to include some of the features being built into the new machine.

M. G. Davenport, Agri. Engineer, TAES

3. Resistance Studies:

These studies at College Station show that American upland and Sea Island cottons may be preferred food plants of the pink bollworm. However, measurements of the number of larvae per unit weight or volume per boll show no species differences. Generally, pink bollworms prefer to deposit eggs beneath the boll calyx on all varieties of cotton regardless of other morphological peculiarities. Among species such as Gossypium herbaceum, G. barbadense var. pima and G. hirsutum var. delta smoothleaf, 80 percent or more of the eggs were deposited beneath the calyx, while only 45 to 50 percent were deposited beneath the bract among species such as G. thurberi, a pubescent variety of G. hirsutum and G. hirsutum var. Deltapine 15. This indicates the latter types may have certain characters which influence pink bollworm moths to oviposit on exposed vegetative parts rather than in the protected areas between boll and calyx.

R. K. Williams, Grad. Res. Asst.
Ento., TAES
D. F. Martin, Entomologist, TAES

4. Evaluation of Preharvest Chemicals:

Moth emergence from boll residues collected in 1955 were recorded through the 1956 growing season. Analyses of moth emergence data showed Kuron-Arsenite to be superior to the other treatments tested, while aminotriazole, arsenite and Shed-a-leaf were slightly less effective. Pentachlorophenol was ineffective. These analyses also showed that winter carryover was greatly reduced by early shredding.

Preharvest chemicals were used in two tests in the Brazos Valley near College Station in 1956. In one experiment the following materials were used:

A - Aminotriazole
B - Pentachlorophenol
C - Arsenite / Kuron
D - Shed-a-leaf
E - Check
F - Arsenite

Preharvest chemicals were applied the last week of October; however, defoliation was better than expected for cool weather. There was little difference in pink bollworm populations between preharvest chemicals, and fewer moths were obtained from early shredded plots.

A second test using a desiccant, arsenite, with several different nozzle arrangements and gallonages was made in the Brazos River Valley. The following treatments were used:

A - Broad-jet - 1 nozzle/40 ft. - 11 gal./acre
B - 5 No. 6 nozzles/row - 30 gal./acre
C - 3 No. 6 nozzles/row - 18 gal./acre
D - 1 No. 6 nozzle/20" - 12 gal./acre
E - Check
F - Shed-a-leaf - Dust

All nozzle arrangements appeared to give adequate coverage; however, the Boom-jet assembly needs additional evaluation. Shed-a-leaf dust appeared to be slightly better for late season application than the spray used in the previous experiment. Fewer pink bollworm moths were obtained from early shredded plots.

During the summer and fall of 1956 a study of the increase in intensity of infestation following defoliation and the effects of post-defoliation applications of insecticides on this increase was made in cooperation with the Agricultural Division, Delta Air Lines. From this study verification of the findings of previous studies was obtained as well as additional information. A decided increase in population was noted following defoliation, but this increase was less than that recorded for undefoliated plots. Generally, the better the defoliation, the less the rate of infestation increase. Post-defoliation applications of DDT (2#/acre) did not reduce the rate of infestation increase. Two tests of cotton properties were made. In one test the infestation ranged from 5.7 to 7.7 mines per boll, and no effect on fiber quality was noted; however, germination and number of good seed were affected. The other test showed adverse effect on lint, seed, fiber quality and classification by an infestation of 15.5 mines per boll. Obstacles to flying which resulted in inadequate coverage of insecticides and defoliants showed a graduation of infestation level, lessening progressively as the rows became remote from the obstacle. The intensity of infestation declined as temperature declined after mid-October.

S. P. Johnson, Plant Physiologist, TAES
W. J. Magee, Entomologist, TAES

5. Evaluation of Treatment Combinations for Pink Bollworm Control:

Two experiments were made to help evaluate the proper timing of DDT for pink bollworm control. In one experiment treatment with DDT was initiated when the following pink bollworm infestation levels were present:

A - Pink bollworm check - endrin
B - 20% injured bolls
C - 80% injured bolls
D - 60% injured bolls
E - 40% injured bolls
F - 10% injured bolls
G - Blooms (500 worms or more per acre)

The pink bollworm population in blooms averaged 818 worms per acre when the test was initiated, but the 60 and 80 percent injured boll levels were never attained. Analyses of insect infestation and yield data showed no differences between treatments. Apparently boll infestations in excess of 40 percent can be tolerated without loss.

A second test was made in which DDT treatment was initiated as follows:

A - Pink bollworm check - endrin
B - Start DDT when bolls are 1 week old
C - Start DDT when bolls are 3 weeks old
D - Blooms (500 worms or more per acre)
E - Start DDT when bolls are 2 weeks old

The initial bloom infestation of pink bollworms averaged 2910 worms per acre. Analyses of insect infestation and yield data showed no significant differences between treatments. Apparently DDT treatment can be delayed until bolls are 3 weeks old without incurring losses.

W. J. Magee, Entomologist, TAES

The cooperative study between the Texas and Louisiana Experiment Stations on evaluation of pink bollworm damage to cotton was continued in 1956. Recent investigations attempted to determine the effect of moderate infestation levels on the yield and quality of cotton. Results obtained indicate that pink bollworm infestation levels up to about 50 percent infested bolls and less than 2 larvae per infested boll cause small, insignificant losses in the value of cotton. Yield differences for seed and lint were insignificant; however, there was a slight tendency toward reduced yields with increased infestation.

J. R. Brazzel, Entomologist, LAES

Laboratory tests were conducted to evaluate the effectiveness of several insecticides against pink bollworm eggs and larvae. In the larval toxicity tests bolls on plants grown in the greenhouse were infested with 10 eggs each and sprayed immediately. Insecticides

and rates were DDT at 1½ pounds, toxaphene 3 pounds, dieldrin 0.3 pound, heptachlor 0.4 pound, endrin 0.4 pound, BHC 0.3 pound gamma, parathion 0.25 pound, Guthion 0.25 pound, and malathion 1 pound. Ten days after treatment bolls were examined for hatched eggs, larval entrance holes above and below the calyx, and number of larvae in each boll.

Only parathion and Guthion caused significantly fewer eggs to hatch than in the untreated check, indicating these two materials exert some ovicidal action. Significantly fewer larvae entered the bolls of all insecticide treatments than entered bolls of the check. This indicates that all insecticides gave some larval control. However, DDT and Guthion stood out clearly as the best two materials tested. In the DDT and Guthion treatments significantly fewer larvae entered the boll above the calyx and more below the calyx than in the check and other treatments. This indicates that the superiority of these two materials may be due to better contact action on larvae that move out from under the calyx to enter the cotton boll. All treatments reduced the number of larvae recovered significantly below that for the check and again DDT and Guthion were outstanding.

Ovicidal action of the same materials listed above was tested on fresh-laid pink bollworm eggs. Technical material in acetone solution was applied to egg masses of 10 each. Approximately 25 microliters of solution was applied to each egg mass placed on a 1 cm. square tab of paper.

The insecticide concentrations required for an LD-50 were DDT - .41%; toxaphene - 4.6%, lindane - 0.23%, heptachlor - 2.2%, dieldrin -.87%, endrin - .28%, malathion - 1.3%, parathion - .009%, and Guthion - .007%.

J. R. Brazzel, Assistant Entomologist, LAES
D. F. Martin, Entomologist, TAES

The cooperative project with Rio Farms, Inc., to determine the value of cotton stalk ensilage for beef production was continued. Results of these tests are not yet complete and shall be reported later.

M. G. Davenport, Agri. Engineer, TAES

SUMMARY OF FINDINGS DURING THE PERIOD 1953-56

1. Stalk Destruction Machinery:

The most effective method of killing pink bollworm larvae in crop debris is by crushing stripped boll residues. The efficiency of the stripper is the most important limiting factor of this method. Perhaps more practical is the suction lifter modification on a standard machine such as the Rotocycle or the use of an ensilage cutter with built-in suction lifter blades such as the Brady machine tested in 1957.

2. Insecticide Application Equipment:

Nozzle drops need not be used for insecticide application. Nozzles spaced 20 inches apart on the boom are sufficient for effective spray coverage. For uniform crop row spacing, one nozzle directly over each row is sufficient. The broad-jet nozzle assemblies appear promising but need additional evaluation. If these assemblies continue to perform well, it is possible that the spray boom can be replaced. This would result in considerable saving of weight and money, and would aid in machine maneuverability.

3. Resistance Studies:

Bolls of a Stoneville 2B x *Gossypium tomentosum* cross appear to be resistant to developing pink bollworm larvae due to a physiological response of the seed to injury. Cell proliferation engulfed and killed many larvae when the seeds were attacked. *G. thurberi* appeared to have resistance because adults avoid it for oviposition due to unfavorable physical characteristics of the vegetative and fruiting parts of this species. A cotton variety having flared or deciduous bracts, tight, straight calyx, coarse pubescence on the vegetative parts and heavy leaf veins should result in the vegetative parts being more attractive to the pink bollworm moth for oviposition than the fruiting parts. Laboratory studies indicate that plant diseases and boll rots are not carried into the boll by the entrance of pink bollworm larvae.

4. Preharvest Chemical Studies:

Pink bollworm populations increase less rapidly on cottons treated with preharvest chemicals than untreated cottons, and this increase varies inversely as the efficiency of application. Post-defoliation insecticide treatments have little effect on population increases. Arsenite used as a desiccant appeared to be the most "fool-proof" preharvest chemical used. Maximum benefit of preharvest chemicals is obtained when harvest and stalk destruction are completed within 3 weeks after application.

5. Combined Production Practices and Quality Studies:

The most effective methods of reducing pink bollworm populations are (1) uniform early planting, (2) the use of insecticides and (3) early destruction of crop residues. An organophosphate, Guthion, was found to be the most effective insecticide used for pink bollworm control. Data obtained during the past 3 seasons indicate that pink bollworm infestations in excess of 40 percent injured bolls and over 2 worms per boll are necessary before significant losses in yield and quality of lint and seed are experienced. In addition recent experiments on late cotton with heavy bloom infestations indicate that treatment with DDT may be delayed without loss until bolls are at least 3 weeks old. Studies on the value of cotton ensilage for beef production indicate that animals will produce weight gains on cotton ensilage but apparently prefer cane. Under certain conditions this substitution might be made. Adult toxicity studies indicate that reduction of pink bollworm populations by insecticide is to a great extent determined by the insecticidal activity of the material on the pink bollworm moth. However, other tests showed a further reduction by contact action on newly-hatched larvae and some ovicidal action.

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BROWNSVILLE ENTOMOLOGY RESEARCH CENTER

Work during the past year has progressed satisfactorily with no serious difficulties arising. Some improvements have been made in equipment, buildings, and land.

The sublaboratory at Port Lavaca was closed during October 1956. At the time of its establishment, Port Lavaca was the most northern point of pink bollworm infestation where insecticide experiments could be conducted. That area is now served on an outlying study area from Brownsville. Upon closing this station, Mr. G. L. Smith was transferred to Tallulah, La., to be in charge of that laboratory. Mr. T. P. Cassidy moved to Brownsville and will continue to devote half-time to flax insects.

M. J. Lukefahr was on leave of absence during the school year while working toward a Ph.D. degree at Texas A. & M. College. His thesis problem pertains to the diapause of the pink bollworm and his investigations will be carried out at Brownsville. Three other members of the Brownsville staff expect to enter school this coming fall to work toward Ph.D. degrees. A. L. Williamson will resume his studies at Texas A. & M.; R. R. Sluss of the Section of Beekeeping and Insect Pathology plans to enter Kansas University; and J. A. Griffin, employed by the State of Alabama and assigned at Brownsville since April 1, 1954, expects to enter Iowa State College.

Two garage and storage buildings were erected last year. These furnish adequate space for all automotive equipment, cages, etc. An insecticide warehouse with a shed for storage of sprayers and other equipment was also constructed.

A tract of farm land adjacent to the laboratory and consisting of 11.21 acres was acquired on a rent-free use basis for experimental purposes. Irrigation water is available. Steps have been taken to acquire on a similar basis an additional 2.68 acres nearby on which is located a 47' x 160' warehouse. This building is presently being used for storage and work space, through an agreement with the International Boundary and Water Commission.

The University of California is planning to move Dr. P. S. Messenger and their three bioclimatic cabinets to California later this year. Mr. Flitters of the Fruit Insects Section is expected to continue the cooperative operation of the remaining seven cabinets.

The Pesticide Chemicals Research Section laboratory, under the supervision of Mr. B. A. Butt, is continuing primary screening against certain cotton insects. Approximately 10 percent of the materials tested by this Section show sufficient promise for testing against the pink bollworm by the Cotton Insects Section.

Insecticides for Pink Bollworm Control - ENT f3-1

1. Field Plot Experiments (McGarr and Smith)

Experiments now in progress show outstanding results from the new insecticide Sevin. Also Thiodan appears promising. For many years DDT has been the most satisfactory insecticide known for control of this insect. EPN was found to be effective but has not proved economical. More recently Guthion or mixtures of Guthion and DDT were found to give better pink bollworm control than DDT alone or mixed with another insecticide for boll weevil control.

These experiments will continue for several more weeks and it is evident that the untreated checks will be severely damaged by the end of the season. The tests have progressed to date under adverse weather conditions and it seems probable that when they are completed the results will show up better than at present. The results to date are shown below.

Experiment	Treatment	Technical insecticide per acre, pounds	Pink bollworm	
			Bolls infested, percent	Larvae per boll, number
No. 1	Untreated check		23.4	.64
	10% Sevin, dust	2.5	1.1	.01
	3% Guthion-5% DDT	0.75-1.25	1.5	.02
	2% Guthion-10% DDT	0.5 -2.5	1.9	.03
No. 2	Untreated check		59.8	1.45
	10% Sevin, dust	2.5	5.0	.07
	4% Thiodan, dust	1.0	24.3	.49
	Guthion, spray	0.5	13.4	.21
	DDT-endrin, spray	2.0 -0.5	26.7	.46

Experiments were conducted last year in the Lower Valley and Coastal Bend areas. In one test, with the heaviest infestation, a gain of approximately 2400 pounds of seed cotton per acre was obtained from 16 applications of Guthion and a mixture of Guthion and DDT. About half of this gain was attributed to pink bollworm control, and the remainder to boll weevil control. Among the other tests, some showed substantial gains in cotton yield, while some did not have enough pink bollworm infestation to reduce the yield appreciably.

Guthion applied as a spray at rates ranging from 0.5-0.8 pound per acre was effective against the pink bollworm and was better than DDT at 2-4 pounds per acre. Also, it was effective at 0.25 pound when mixed with DDT at 2.0 pounds per acre. EPN applied at 0.5 pound per acre plus 1-2 pounds of DDT was likewise effective.

2. Laboratory Screening Tests (Bottger, Tsao, and Lowry)

In laboratory tests at Brownsville, 240 chemicals were tested as direct contact sprays against pink bollworm moths. Those found to compare favorably with the DDT standard were also tested for residual effectiveness against moths and larvae on sprayed bolls. In the direct spray tests, six chemicals that were of about equal effectiveness to DDT are American Cyanamid 12503, Ent. 20274, Ent. 20410, and Monsanto 7394, 9333, and 10561. Six that were more effective than DDT are Union Carbide 7744 (Sevin) and 8305, Ent. 21170, Ent. 20143, Hercules 3004, and Thiodan. Based on LC-50 values in the residual spray tests on cotton plants, six chemicals found to be about as effective as DDT are Union Carbide 7744, Ent. 21170, General Chemicals 3707, and Monsanto 7769, 9533, and 10561. Hercules 3895, Bayer 25141, and Thiodan were found to be about 4, 6, and 11 times, respectively, more effective than DDT on the basis of the LC-50. When tested as residues against first-instar larvae, Bayer 25141, Union Carbide 7744, Hercules 3895, and Monsanto 9533 and 10561 were as effective as DDT, while Thiodan and General Chemicals 3707 were less effective.

No synergistic action of Guthion combined with DDT is indicated from laboratory tests. When sprayed on cotton plants at the rate of two pounds per acre, one-, three-, and five-day old deposits of DDT resulted in higher pink bollworm moth mortality than the mixture containing three parts DDT to one part Guthion. Mortalities resulting from Guthion alone, at the rate of 1/2 pound per acre, were greater than from the mixture in two out of three tests.

Preliminary studies of translocation employing radioactive insecticide, Bayer P^{32}-19639, on cotton plants resulted in five general observations. First, there was little translocation of the chemical from treated to untreated leaves. Second, plants picked up the chemical readily from treated soil. Third, plants grown from seeds coated with P^{32}-19639 in charcoal showed the highest radioactivity in roots, and the least in stems. Fourth, squares did not show any significant radioactivity in any of the treatments. Fifth, there was high radioactivity in soil more than 1 foot below where treated seeds were planted.

3. Screening of Attractants and Repellents (McGough, Lukefahr, and Griffin)

If certain chemicals are found to be highly attractive to cotton insects they might be incorporated with insecticides and applied to only portions of a field to attract and kill the insects from surrounding areas. Also, attractants might be useful in detecting new infestations of the pink bollworm. Chemicals are being screened as attractants for the pink bollworm and boll weevil in olfactometer tests. The Pesticide Chemicals Research Section is cooperating in

this work by supplying samples of many chemicals, some of which are derivatives of the cotton plant.

The catches of pink bollworm moths were very low in traps containing 26 materials tested as attractants in a cotton field; however, 4 of the chemicals possibly warrant further investigation. Of 21 other chemicals tested at various dilutions in an olfactometer, none were appreciably more attractive than cotton bolls. Some other chemicals sprayed on caged plants were considered as attractants or repellents depending on whether or not they caused an increase or decrease in the number of eggs laid on the treated plants compared to the number on untreated plants. Of 64 materials evaluated on this basis, 9 appeared to be attractive to the moths while the others showed slight to considerable repellent action.

Experiments Toward Developing Methods for Pink Bollworm Eradication ENT f3-1 and 3.

Work was carried out to provide information relative to possible use of chemicals and winter cultural practices for eradicating the pink bollworm in relatively small isolated areas or in lightly infested, fringe areas. Original plans for the work included a proposed attempt to eradicate an isolated infestation. However, this eradication phase did not materialize owing to failure to find a suitable isolated infestation. The experiments conducted were laboratory and cage tests with chemicals applied against overwintering larvae and a large-scale field experiment with foliage applications followed by grazing to reduce the overwintering population.

1. Laboratory and Cage Tests (Bottger, Tsao, and Lowry)

Results of laboratory contact tests indicate that parathion, Guthion, and lindane are slightly more effective and faster acting than aldrin, DDT, and endrin when overwintered larvae contact fresh deposits of these insecticides. Similar larvae exposed to the possible fumigant action of these insecticides were not visibly affected by any of them. Pyramid screen cages were used to test two different methods of treating infested seed cotton: (1) Overwintered seed cotton was buried under 2 inches of soil and the soil surface was then sprayed with the insecticides, and (2) seed cotton was sprayed and then buried beneath 2 inches of soil. Examination of samples of the larvae in both treatments indicates that very little mortality occurred while the larvae remained in the seed. Moth emergence from material in both treatments indicates that endrin and lindane were the most effective, and Guthion the least effective of the six insecticides used. A comparison of the results also indicates the superiority of spraying the cotton residue prior to working it under rather than spraying the soil

surface after the residue has been buried. In the former treatment, endrin at 20 pounds and lindane at 10 pounds per acre gave respective mortalities of 93 and 87 percent. Assuming that a higher dosage would eradicate an overwintering population, such a measure would be very expensive, if not beyond the realm of feasibility.

2. Large-Scale Experiment with Foliage Applications Followed by Grazing (Richmond and Robertson)

In cooperation with the Plant Pest Control Division, experiments were conducted to obtain information on reducing pink bollworm populations in a heavily infested territory to prevent spread into noninfested territory. Moth migration is stimulated by the development of high infestation and subsequent scarcity of food for reproduction late in the season. Control practices that prevent high populations will reduce this hazard. Also, such practices might be used in conjunction with other measures in an eradication program.

DDT was applied by airplane on 25-acre plots, one plot on each of three farms in the Brazos River Valley near College Station, Texas (Baker, Chance, and College farms). Since DDT is not effective against the boll weevil, endrin was added for control of this insect. Endrin alone was applied on check plots about 3 acres in size. The plots receiving these treatments were compared with adjacent acreage which the owners treated according to their own choosing. Shortly after harvest the fields were opened to a sufficient number of cattle for grazing the cotton rather thoroughly within a period of about 3 weeks. The cattle were not confined in the fields but were free to go in and out, returning to their previous pasture at will.

Results obtained from the three experiments are summarized below.

Date	Endrin, 0.4 lb. (check) 1/	Farmer control program 2/	DDT 2.0 lbs. + endrin 0.2 lb. 3/
	Larvae per acre in green bolls		
8/7	75,198	42,503	19,164
8/20	196,768	71,613	36,318
9/5	279,458	123,876	39,451
9/17	461,779	283,627	50,553
10/1	132,624	220,152	43,467
Average	229,165	148,354	37,791
% reduction under check		35	83
	Pounds of seed cotton per acre		
	2,779	3,291	4,054
	Resting larvae per acre		
No. after harvest	20,595	18,023	5,952
% reduction under check		13	71
No. after grazing	1,921	900	608
% reduction by grazing	91	95	90

1/ Not effective against the pink bollworm.
2/ Nine applications containing DDT on Baker and College farms after tests were begun on July 21; 5 applications on Chance farm.
3/ Sixteen applications at 5-day intervals beginning on July 21 on Baker and College farms; 15 applications on Chance farm; 4 of these applications were made after chemical defoliation.

It will be noted in the above table that 15-16 insecticide applications for pink bollworm control greatly reduced the population under that of the check plots, or the farmer control program in which 5-9 applications were made, and the pink bollworm control was reflected in increased cotton yields. Control during the growing season greatly reduced the resting-stage population present after harvest despite heavy moth migration into the plots late in the season.

A critical factor in reducing the fall population is the necessity for preventing regrowth of the plants after chemical defoliation, or preventing buildup of the larval population on such regrowth by continued insecticide applications when harvest and stalk destruction are not carried out promptly. Also, the green bolls present at the time of defoliant applications should be protected by further insecticide applications. Examination of green bolls about 25 days

after defoliation showed that 15 percent of the bolls contained eggs, indicating that under conditions of heavy migration the moths continued to oviposit despite a leaf-drop of approximately 85 percent due to the defoliant. The potential overwintering population was reduced 71 percent by the DDT-endrin treatment, and this lowered population was reduced slightly more than 90 percent by grazing. Previous experiments have shown that the population remaining after such treatments may be further reduced by early stalk shredding and plowing.

Biological Control - ENT f3-2

1. Imported Parasites and Predators (McGough and Noble)

During the period from 1953 through 1955, five species of parasites and one predator, shipped from India through the Moorestown, N. J., laboratory, were propagated for release in large numbers. A major portion of the adults reared were released in the Lower Rio Grande Valley of Texas with some in the adjacent area of Mexico. The others were released in the Eagle Pass, College Station, and Coastal Bend areas of Texas. The releases were discontinued at the end of the 1955 season after extensive field collections failed to show that any of the species had become established. Further efforts to recover the parasites in 1956 consisted of caging a 500-boll sample collected at, or in close proximity to, each of 84 liberation sites in Cameron County. Several native parasite species were recovered in the cages but none of the imported parasites were present. It is believed that the sampling has been adequate to determine if the species were maintaining themselves, even in small numbers, and on the basis of the negative results, it is concluded that none of the imported parasites have become established in this country.

It also appears that the predaceous coccinellid, Chilomenes sexmaculata, did not become established. In 1955, adults and larvae were found in Cameron County after about four generations had developed, but scouting since that year at 24 liberation points gave negative results.

2. Pathogenic Organisms (Sluss)

Work with pathogenic organisms is conducted in cooperation with the Section of Beekeeping and Insect Pathology. That Section supplied this laboratory with cultures of the bacteria Bacillus thuringiensis and Serrata marcesens, several species of entomophagous fungi, and DD 136 nematodes from the laboratory at Beltsville, Md. Laboratory screening of these pathogens was conducted against the pink bollworm, boll weevil, and several other economic insects in the Brownsville area. Some field testing has been done and should be expanded.

B. thuringiensis gave 16 percent control of first-instar pink bollworm larvae on potted plants under outside conditions. S. marcesens was found to be pathogenic to pink bollworm larvae under laboratory conditions. Laboratory tests have shown several species of entomophagous fungi to be pathogenic to pink bollworm larvae and boll weevil adults.

Laboratory tests have shown that pink bollworm larvae in bolls and boll weevil larvae in squares are susceptible to attack by DD 136 nematodes. Field tests have shown DD 136 nematodes capable of attacking pink bollworm larvae in blooms and effecting 90 percent control of dormant larvae on the soil surface and buried 2 inches deep. This test on dormant larvae was conducted under very moist conditions; under much drier conditions, no control was obtained.

Field tests are presently underway to determine the effect of nematode DD 136 against boll weevils infesting squares. Further field tests are also planned to determine the effectiveness of B. thuringiensis and DD 136 nematodes against pink bollworm larvae.

A large stainless steel funnel was constructed to collect nematodes as they emerge from wax moth larvae which are used as laboratory hosts. The funnel saves time in collecting and gives yields equal to those obtained by petri dishes or trays.

In laboratory tests favorable results have been obtained with the following pathogens and insects: DD 136 nematodes vs. cotton leafworm larvae, cotton looper larvae, southern armyworm larvae, salt-marsh caterpillar larvae, and diamondback moth larvae; entomophagous fungi vs. salt-marsh caterpillar larvae and southern armyworm larvae; polyhedral virus vs. cabbage looper larvae; Bacillus thuringiensis vs. cotton leafworm larvae and Pieris monuste larvae.

Cultural Control - ENT f3-3

In the conduct of various experiments, some rather precise information on cultural control methods has been obtained. (See also the hibernation studies - ENT f3-6 on page 24).

1. Observations in Central Texas (Fife)

Studies on winter survival of the pink bollworm in Central Texas indicated a low survival when stalks were shredded and the land plowed so as to bury most of the crop residue during the fall and winter months. High survival was indicated when bolls remained on or near the soil surface throughout the winter. The use of strippers to harvest the cotton crop appears to be highly desirable from the standpoint of reducing the overwintering population. The most

important factors influencing winter carry-over were (1) The degree of late-season infestation and number of green bolls after September 15; (2) the amount of infested waste cotton left in the field; (3) the date and method of stalk destruction; (4) the depth and date of plowing under the crop residue.

2. Stalk Shredder Experiments (Robertson and McGarr)

Machinery used in stalk destruction and land preparation is being evaluated for pink bollworm control. A Brady machine manufactured for the purpose of cutting and shredding silage, and loading it into a vehicle during the same operation, was tested as a cotton stalk shredder. The machine operates in a beater fashion similar to a hammer-mill and has sufficient suction to load the silage without the use of a fan. The conveyor tube used to load silage was removed and the machine converted so that it distributed the shredded material uniformly on the soil. The converted machine produces sufficient suction to lift the shredded material and almost all the original cotton debris on the soil surface, and blow it through the housing at high velocity. In two tests conducted on green cotton in the Brownsville area this machine was compared with a conventional shredder commonly used to cut cotton stalks. Samples collected before and immediately after shredding were placed in moth emergence cages with traps for recovering the moths to determine effectiveness of the machines in killing pink bollworms. The results from the Brady shredder and a Rotocycle shredder are shown below.

Machine	Number of moths Before cutting	Number of moths After cutting	Percent reduction
Brady	1420	270	81.0
Rotocycle	1420	736	48.2

Since the Brady machine will lift most of the cotton from the ground by suction, it could be used a number of times following the original shredding, presumably reducing the larval population each time. Such multiple operation has not been tested.

3. Grazing Experiments (Robertson)

The early work with the pink bollworm in western Texas has shown that heavy grazing by cattle was very effective in reducing the overwintering larvae when the cattle were confined in cotton fields without other food. Experiments were conducted on the 1956 crop at College Station and San Angelo to determine the effectiveness of grazing when livestock were not restricted to the cotton alone.

In the experiment at College Station, two fields were grazed before frost, and the cattle were free to return to the adjoining pasture at will. The cattle had access to the fields for about 3 weeks, after which the cotton had been rather thoroughly grazed. They were then removed, the stalks shredded, and the fields plowed.

At San Angelo the livestock were free to graze the fields at will and were fed some hay and concentrates during this period, which was after frost. Records were obtained on three farms grazed as follows: (1) Alley Farm, 15 acres grazed by 40 sheep and 6 cows from December 5 to January 23; (2) Balding Farm, 15 acres grazed by 20 sheep and 10 cows from November 20 to February 12; (3) Sheffield Farm, 40 acres grazed by 300 sheep, December 4-27.

The pink bollworm populations were determined by moth emergence from samples taken before and after grazing. The results are shown below.

Localities (Texas)	Farm	No. resting larvae per acre		Percent reduction
		Before grazing	After grazing	
College Station	College	7,762	883	89
	Chance	27,457	1,905	93
San Angelo	Alley	11,072	667	94
	Balding	387,200	0	100
	Sheffield	6,337	500	92

Grazing of cotton fields following harvest, provided there is no insecticide residue that may be harmful to livestock, has definite promise as an aid in reducing the overwintering population in some areas. At San Angelo most of the fields are fenced and there are many cattle and sheep on the farms. Feed is frequently scarce in that semi-arid area. The pink bollworm infestation is usually high, due in part to dry and relatively mild winters. In East Texas grazing of cotton fields would be profitable on many farms and this practice would aid in controlling the pest. Most cotton fields are small and machinery may be less feasible than grazing under such circumstances. Grazing appears to be a very practical method, possibly in addition to regulated stalk destruction and subsequent plowing to bury the remaining debris.

Hibernation Studies - ENT f3-6 (Robertson, Fife, Smith and Noble)

Hibernation experiments on the pink bollworm have been in progress ever since research on the insect was started in the United States in 1927. Since 1943 the experiments have been conducted with an improved type of cage which affords more reliable data. Owing to

quarantine regulations the early work was confined to the heavily infested areas of western Texas.

In 1952, tests involving four uniform treatments were started at eight newly infested and widely separated localities in Texas and Oklahoma, with the intention of repeating the experiments for 5 years. The work will be completed this year and a manuscript is now being prepared for publication as a U.S.D.A. Bulletin. Other treatments have been added at some of the localities and more recently tests were begun at other localities using a new technique. Tests are being conducted in bioclimatic cabinets simulating conditions in representative localities of the Cotton Belt outside of the infested area. The presently incomplete records for 1956-57 are not discussed in the report below.

1. Tests at Eight Localities

Experiments are now in the fifth year at Brownsville, Port Lavaca, Waco, Greenville, Mount Pleasant, Lubbock, and Vernon, Texas, and at Chickasha, Okla.

Four-Year Results with Similar Treatments.--Survival at the different localities varied widely, and there has been considerable variation from year to year. The 4-year average figures show that fall burial caused the highest mortality at localities with mild temperatures and heavy rainfall--that is, at Brownsville, Port Lavaca, and Waco, Tex. In localities with colder winter temperatures--that is, at Lubbock and Vernon, Tex., and at Chickasha, Okla., the mortality was highest in bolls above ground simulating conditions on standing stalks. Greenville and Mount Pleasant, Tex., appear to be so situated that the mortality in these localities is highest in bolls above ground in some years, while in others it is highest in bolls buried in the fall. Fall burial increased mortality above that for bolls remaining on the soil surface until buried in the spring at all localities except Lubbock where there was no significant difference. Mortality was lowest in bolls that remained on the soil surface throughout the experiment at all places except Brownsville where the lowest mortality occurred in bolls kept above ground during the fall and winter.

In interpreting these results, consideration must be given to the proportion of infested bolls on the stalks or soil surface following harvest. Practically all waste bolls where a stripper has been used are left on the soil surface. Where cotton is harvested by hand or machine pickers, the amount of waste cotton and the proportion on the soil surface may vary widely. In a cold climate immature bolls may not contribute to the overwintering population even though heavily infested. Such watery bolls are easily frozen and the larvae killed if there is a sudden freeze following warm weather.

Other Treatments.--Water applied in the spring, simulating preplanting irrigation, increased mortality at Brownsville. It has been noted in dry springs at Lubbock that moth emergence was delayed and the mortality probably increased due to lack of moisture to stimulate pupation. Spring irrigation appeared to reduce mortality in 1956. Results with cover crops at Mount Pleasant were erratic, probably due to irregular stands and rather poor plant growth; however, there appeared to be an increase in mortality when the cover crops were plowed under after January 31. The treatments with and without cover crops, including burial dates of November 15, January 31, March 1, and April 1, showed that the earlier infested bolls are buried, the higher is the pink bollworm mortality.

2. Tests at Other Localities with New Technique

Experiments were initiated at Beaumont, Nacogdoches, and Texarkana in the fall of 1955 and at Kirbyville and Tyler in the fall of 1956. Infested bolls were exposed, under various treatments, during the winter and then moved to Brownsville for moth emergence in cans held under conditions favorable for pupation. This method appears satisfactory for obtaining information on the periphery of the infested area where there would be a hazard from leaving the test material in cages during the cotton-growing season. The average percentage mortality from four different cultural treatments for the winter of 1955-56 was 85.7 at Beaumont, 82.9 at Nacogdoches, and 97.44 at Texarkana. There was a relatively low mortality (89.4 percent) from bolls buried in the fall at Nacogdoches.

3. Tests in Bioclimatic Cabinets

Experiments were conducted in bioclimatic cabinets reproducing conditions at Greenwood, Miss., and Malden, Mo., in the winter of 1955-56. At Malden there was no survival in two environments--bolls buried in the fall and bolls left on the soil surface, with 570 larvae in each environment. There was 0.13 percent survival from 1,546 larvae in seed kept on sand in cans. At Greenwood there was a survival of 18.2 percent in bolls on the soil surface. No survival occurred in 1956 from bolls buried in the fall at Greenwood but there was some survival for this environment in another experiment conducted the previous year. The percent survival in bolls held in ventilated containers above ground without any rainfall was 76.7 at Greenwood and 8.8 at Malden. The Malden experiment is being repeated in the winter of 1956-57 and similar experiments were initiated in other cabinets simulating conditions at Memphis, Tenn., and Athens, Ga.

Infested seeds were placed in other bioclimatic cabinets being used for fruit insect investigations. Of 1,546 larvae placed in Fort Valley, Ga., climate on October 15, only 2 pupated and emerged the

following spring. For a similar lot placed in the Orlando, Fla., cabinet on December 23, the survival was 6.85 percent. Heavy rainfall and decay of the seed evidently reduced survival in both of these climates. Resting larvae placed in Compton, Calif., climate on March 23 pupated and emerged during the period from the first of July through the middle of December. Infested seeds are now being exposed in other fruit fly cabinets simulating conditions at San Jose and Sebastopol, Calif., Tempe, Ariz., and Houma, La.

On the basis of bioclimatic cabinet studies it now appears that the pink bollworm can survive the average winter at all locations throughout the Cotton Belt if given favorable hibernating conditions.

Pink Bollworm Abundance and Distribution - ENT f3-7 (Various staff members and Plant Pest Control Division)

This subject is discussed in the Plant Pest Control Division report, pages 2-4. Information on the 1957 crop for the Lower Rio Grande Valley was obtained from early-season bloom inspection, including surveys to find suitable fields for insecticide experiments. These surveys showed spotted heavy infestations in some early plantings which attracted moths emerging in surrounding late-planted fields. Although there was an increase in infestation this year over the past several years, the total acreage with heavy initial infestation was small. The decrease in infestation following the severe outbreak in 1952 is shown in early-season bloom inspection records tabulated below.

Year	Inspected	Infested	Percent fields infested	Number of blooms		No. worms per 100,000 blooms
				Inspected	Infested	
1952	1,031	956	93	1,384,530	34,091	2,462
1953	961	622	65	2,596,748	4,809	185
1954	455	59	13	1,132,569	199	18
1955	482	118	24	1,517,426	483	32
1956	442	46	10	1,201,157	136	11
1957	528	188	35	1,297,168	1,614	124

Highly effective pink bollworm control in this area since 1952 has been brought about primarily by the thorough execution of the cultural control program which consists of a regulated planting date and a stalk destruction deadline of August 31.

Alternate Host Plants - ENT f3-10 (Shiller, Fife, and Smith)

Discovery of eight additional pink bollworm host plants since the last issue of this report makes a total of 37 plant species, other

than cotton, on which the insect is known to propagate in the United States. These species represent 4 families and 18 genera, but most of them belong to the family Malvaceae. Fruiting pods of 24 of the known hosts have been found to carry larvae through the winter season. Because of their lack of abundance or attractiveness to the moths, none of the wild hosts appear to be a great factor in building up the pink bollworm population to attack cotton. However, some of the alternate hosts may permit survival and thus would be of primary importance in a program for eradicating the insect by means of a non-cotton zone or cotton-free period.

The plants found to be hosts of the pink bollworm in the United States are listed below.

Malvaceae:

*Abutilon incanum (Link) Sweet
*Abutilon lignosum (Cav.) Don
Abutilon trisulcatum (Jacq.) Urban
*Althea rosea (L.) Cav. - Hollyhock
Callirhoe linearifloba (T&G) Gray
*Gossypium thurberi Todaro - Thurber cotton
*Hibiscus abelmoschus L. - Muskmallow
*Hibiscus cannabinus L. - Kenaf
*Hibiscus cardiophyllus Gray
*Hibiscus coccineus Walt - Scarlet rosemallow
*Hibiscus esculentus L. - Okra
*Hibiscus lambertianus HBK
Hibiscus lasiocarpus Cav. - Wooly rosemallow
*Hibiscus militaris Cav. - Scarlet rosemallow
Hibiscus mutabilis L. - Cottonrose hibiscus
*Hibiscus rosa-sinensis L. - Chinese hibiscus
*Hibiscus syriacus L. - Shrub althea
Hibiscus tubiflorus D.C.
Kosteletzskya althaeifolia (Chapm.) A. Gray
*Malachra capitata L.
Malva parviflora L.
Malva sylvestris L.
Malvastrum coromandelianum (L.) Garcke
Malvaviscus arboreus Cav. - South American waxmallow
*Malvaviscus drummondii T&G - Drummondii waxmallow
*Pseudabutilon lozani (Rose) Fries - Lozano false abutilon
*Sida cordifolia L.
*Sida spinosa L.
*Thespesia populnea (L.) Correa - Portia tree

Euphorbiaceae:

*Croton capitatus Michx. - Goatweed
*Croton texensis (Kl.) Muell. Arg. - Goatweed
*Ricinus communis L. - Castor bean

Leguminosae:
*Daubentonia punicea (Cav.) DC - Coffee bean (Sesbania punicea)
*Prosopis chilensis (Molina) Stuntz - Mesquite
*Gleditsia triacanthos L. - Honey locust

Convolvulaceae:
*Ipomea crassicaulis (Benth) Robinson - Bush morning glory

Linacea:
Linum usitatissimum L. - Flax (infested in cage)

* The fruiting forms of plants found to carry resting larvae over the winter.

Physiology - ENT f3-13 (Clark and Williamson)

The respiratory studies of all stages of the normal pink bollworm at 82° F. yielded four general observations in regard to the respiratory rate. First, there is no apparent difference in the rates between the sexes in the adult stage. Second, the respiratory rates of the non-diapause fourth-instar larvae, the pupae, and the adults are approximately the same. Third, the diapause fourth-instar larvae have a lower rate than the non-diapause larvae. Fourth, the rate of the webbed diapause fourth-instar larvae was much lower than the non-webbed diapause larvae.

Temperature studies between 100° and 120° F., although not yet completed, present two tentative conclusions. First, temperatures up to 112° F. for 24 hours have no apparent deleterious effects. Second, the temperature region bringing about heat rigor apparently spans several degrees somewhere in the neighborhood of 115° F. When larvae were exposed to 120° F. there was an increasing death rate with increasing period of exposure until an exposure of two hours was reached, after which all were killed. Larvae exposed to 125.6° F. for 14 minutes at a humidity of about 98 percent had a mortality greater than 80 percent. At this same temperature, but at about 15 percent relative humidity, there was complete kill. All exposed to 125.6° F. for 30 minutes were destroyed.

In connection with the temperature studies a method was developed to drive larvae out of cottonseed in a Berlese-type collecting apparatus, thus helping to meet a need for an efficient method of obtaining larvae for experimental use. The critical part of the apparatus is the heater unit which consists of a nichrome wire grid strung across the top of a shallow box. The larvae were conditioned by moistening the cottonseed and placing it in a temperature and humidity controlled room at 90° F. and 85 percent relative humidity for 2 days. The seeds were then placed in the collecting apparatus and held at a temperature of approximately 110° F. To date the

results have shown that 85-95 percent of the larvae can be driven from the seed in 1 hour. At present most of the larvae used in the laboratory are being supplied by this apparatus. Research is now being carried out to try to establish a consistent percentage yield. If this can be done the apparatus can be used to obtain infestation records.

Attempts to drive the larvae from seed through the use of infra-red lamps have failed. The seed used, however, were not conditioned by moistening and holding in high humidity prior to the treatments.

Ecological Investigations - ENT f3-14

1. Life History and Habits (Lukefahr, Griffin, and Noble)

Studies of the life history and habits of the pink bollworm were made in the insectary, in field cages, and in a bioclimatic cabinet where temperature, humidity, and light intensity were controlled. Some of this work was a continuation of previous investigations and was necessary to complete or confirm the previous data.

The moths were found to mate between 2 a.m. and 5 a.m. They mated at ages of from less than 1 day to 8 days, with 40 percent of the pairs copulating the first night after emergence and over 80 percent by the end of the third night. Twenty-eight percent of the pairs copulated two or more times with a maximum of five times.

There was no moth activity during full daylight and no appreciable oviposition until after the light intensity dropped below 3 foot-candles in the evening. A light intensity of 0.02 foot-candle or less appeared to be optimum for egg deposition and other activity. Approximately 50 percent of the eggs were laid between the hours of 8 p.m. and 10 p.m., and over 80 percent by 12 o'clock midnight. Temperatures between 70° F. and 90° F. did not alter the oviposition pattern of the moths. At temperatures below 70° F., oviposition decreased and at temperatures below 65° F. moth activity ceased. Relative humidities between 50 and 90 percent did not influence either oviposition or other moth activity. The moths were observed to feed throughout the period of activity which was during darkness and lasted from about 7 p.m. to 5 a.m.

Bolls were found to be the preferred place for oviposition, accounting for 31.5 percent of the eggs recovered. The plant terminals were second in preference with 25 percent, the leaves and leaf petioles being next in order with 12.9 and 10.9 percent respectively. The remainder of the eggs were distributed about equally over the rest of the plants.

Various sugars were found to be suitable diets for the moths. Groups fed on a fructose and glucose mixture, glucose, sucrose, and simulated cotton nectar, laid numbers of eggs descending in the order of the respective diets. However, the difference in number of eggs laid between groups was small. Moth longevity was about the same for all groups regardless of diet. Also, previous work has shown that the absence of food, other than water, did not decrease moth longevity but greatly decreased the number of eggs laid. In a preliminary test conducted with cotton growing in large screen cages, a nectariless variety greatly limited the pink bollworm population buildup, presumably due to the lack of nectar as food for the moths. The information obtained on nectariless varieties is a promising lead for further work.

Pink bollworms developing in squares usually reach maturity or the fourth instar by the time the squares develop to the flower stage. Tagged squares, infested by hand at various ages, showed that the larval development period decreased as the square age at the time of entry increased. Thus, the larvae in the older squares were permitted to complete feeding by the time the bloom opened and leave the plant without causing injury to the young boll beneath the bloom. The larval periods of the various groups ranged from 9.4 days for squares infested at 19-21 days of age to 16.7 days for squares infested at 9-10 days of age. Squares less than 11 days old when infested shed from the plants, and few larvae developed in these.

The developmental period of larvae feeding in bolls was longer than that for larvae in squares. As in the case for squares, the larval period of the boll broods decreased when the boll age at time of their entry increased. The larval period of the various groups ranged from 12.1 days for bolls infested at 31-40 days of age to 22.4 for bolls infested at 1-10 days of age. The percentage of larvae entering the diapause increased with the age of the boll. Length of the diapause period was influenced by both humidity and temperature, i.e., a high relative humidity was necessary to stimulate pupation under favorable temperatures.

When cotton infested with pink bollworms is plowed under, the larvae are exposed to a variety of conditions depending on depth of burial, soil type, and amount of vegetation, both the amount plowed under and that growing later, such as cover crops. In preliminary laboratory tests, designed to obtain some information on this subject, a carbon dioxide rich atmosphere caused a rather high larval mortality, while a carbon dioxide deficient atmosphere had little effect on survival but resulted in a prolonged pupation period. Larvae in an oxygen rich atmosphere pupated at a slightly slower rate but had a considerably higher survival than the check larvae. Larvae in an oxygen deficient atmosphere were all alive at the end

of 1 week which indicated a low rate of metabolism in the diapause stage; however, there was a 100 percent mortality at the end of the second week.

2. Work with Radioactive Isotopes (Clark and Glick)

Laboratory studies on the effect of P^{32} on the pink bollworm showed that there was no apparent injury to the moth fed the usual amounts of radiophosphorus tagged sugar solution. Further, the amount ingested did not affect the viability of the eggs laid by the tagged moths. The eggs were made radioactive, however, and could be detected easily on cotton plants using the usual portable ratemeter. The results of the field releases of tagged moths again showed the influence of wind on moth flight. At very mild velocities, such as 2 m.p.h., the moths moved with the wind.

3. Moth Flight Studies by Airplane Collections (Glick)

Eleven moths were caught in airplane traps in the Brazos Valley between Waco and College Station, Tex., with two at 200 feet, five at 500 feet, three at 1,000 feet, and one at 2,000 feet. The extreme drought in that area greatly reduced the infestation except in irrigated fields, many of which were effectively treated with insecticides that held the infestations in check. Two moths were caught over the Red River in Arkansas and Louisiana between Shreveport and Texarkana. One of them was at 500 feet and the other at 2,000 feet. These collections indicate possibility of spread through flight even though quarantine stations are maintained on principal highways.

Killing Pink Bollworms in Cotton Gin and Oil Mill Products - ENT f3-14

Work on this subject was carried out in cooperation with the Agricultural Engineering Division and the Plant Pest Control Division. As previously reported, it has been found that the simplest saw gins kill 85 percent of the pink bollworms in cottonseed caught at the gin stand, and with the gradual addition of other machinery ultimately comprising an elaborate ginning system, the kill is increased to more than 99 percent. Owing to this high kill plus further mortality after ginning either in the oil mill processing or planting seed treatments, it was concluded that the survival in cottonseed is of little, if any, importance when the seed is used within the infested area. These findings led to the abolishment of regulations requiring heat treatment of cottonseed at gins in Texas and New Mexico.

Tests were conducted during 1954 and 1955 with fans commonly used at gins for handling trash and at oil mills for moving motes and linters to the press. It was found that such fans, operated under

certain specifications, killed all pink bollworms in the gin waste and oil mill products. Based on the results of these tests, the Pink Bollworm Control Project issued regulations for the use of single fans for treatment of gin waste and oil mill products. The housing or scroll of the fans used in the tests was not lined with rubber, and the specifications designated that no fan could be approved for treatment of gin waste and oil mill products where the housing was lined with rubber. However, ginners have found that by lining the housing with rubber the wear on the housing is decreased, thereby reducing the maintenance cost.

1. Tests with Rubber-Lined Scroll (Robertson and other staff members)

Tests were conducted in November 1956 and March 1957 at the Southwestern Cotton Ginning Research Laboratory, Mesilla Park, New Mexico, to determine whether fans with rubber-lined housing were as effective in killing pink bollworms as fans with steel or cast iron housing. A number 30 Murray rubber-lined fan with a 19-inch, 6-straight blade, wheel was used at speeds near the minimum approved for unlined fans in treating gin trash and oil mill products.

Tests with Gin Waste.--Heavily infested cottonseed ginned on a roller gin to prevent injury to the larvae were mixed with infested gin waste at the rate of 1 pound of cottonseed to 4 pounds of gin waste. Each lot of material was mixed as a separate sample and each treatment was replicated four times. Tests were made at two fan speeds. Results of hand examination of samples were as follows:

Fan Speed (RPM)	Tip Speed (F/M)	Number of Larvae	
		Before Treatment	After Treatment
2520	12500	168	0
2730	13563	546	0

Tests with Oil Mill Products.--Cottonseed was obtained by ginning cotton on a roller gin. The seed was added to oil mill products at the following rate:

Linters	9 lbs. to 1 lb. seed
Motes	9 lbs. to 1 lb. seed
Hulls	4 lbs. to 1 lb. seed

Each lot of material was mixed as a separate sample and each treatment was replicated three times. The fan was operated at two speeds. The material was fed at the normal rate that the material would be passing through a fan at the oil mill. The feeding rate was as follows:

Linters	10.5 pounds per minute
Motes	0.69 pound per minute
Hulls	32.0 pounds per minute

All the material from each replicate was examined by hand. Results were as follows:

Fan speed (RPM)	Tip speed (F/M)	Material	Number of larvae	
			Before treatment	After treatment
2470	12300	Linters	501	0
		Motes	501	0
		Hulls	501	0
2700	13420	Linters	501	0
		Motes	501	0
		Hulls	501	0

Discussion.--Results of these tests agree with those of the previous tests with unlined fans and show that rubber-lining of fan housings had no effect on the kill of pink bollworms. There were no live worms found in the samples of gin trash treated at either 2520 or 2730 r.p.m. The latter speed is about the minimum required for a 19-inch wheel trash fan and the former is below the minimum requirement, as specified in the regulations for treatment of gin trash. Samples of linters, motes, and hulls showed no survival after passing through a rubber-lined fan. The speed of 2470 r.p.m. was about the minimum required, as specified in the regulations for the treatment of linters, motes, and hulls.

2. Hot Water Treatment of Seed to Hasten Germination (Clark and Williamson)

A recently adopted method of treating planting seed, particularly American-Egyptian variety, consists of immersing the seed in water at temperatures between 160° and 180° F. for not less than 1 minute or more than 2 minutes. Such treated seeds may be returned to storage and retain the quick germinating qualities. An experiment was conducted to determine if this treatment would destroy pink bollworm so as to permit movement of the seed out of the quarantined area. Infested seeds were immersed in water at temperatures of 130°, 140°, 150°, 160°, and 180° F. for intervals of 45, 80, and 120 seconds. There was no pink bollworm survival at 150° F. or higher for 45 seconds, the shortest time exposure. It therefore appears that seeds receiving this treatment are safe to move to noninfested territory without danger of spreading the pink bollworm.

Nutritional Studies - ENT f3-16

1. Rearing on Artificial Media (Vanderzant)

The most marked effect of lipide deficiency in the diet of pink bollworms is the failure of the moths to emerge from their pupal cases. At suboptimal levels of corn oil or linoleic acid a few moths emerged normally, but most emerged only partially.

There is a rapid development of oxidative rancidity in unsaturated fatty acids held in storage. The development of this rancidity destroyed the biopotency of the acids, as was expected. These factors prompted investigations with the stable urea adducts of the unsaturated fatty acids. It was found that urea adducts can be satisfactorily substituted for the acids in the rearing medium. Linolenic acid was found to have a higher biopotency, as measured by moth emergence, than linoleic acid.

When other lipides were tested for their effect on pink bollworm development emergence appeared to increase with the amount of unsaturation.

Larvae failed to grow when any one of the ten essential amino acids, as determined for the young rat, was omitted from the diet. Adults were obtained when only the essential acids were used to satisfy the amino acid requirements. However, growth was slow and the pupae were small. Various ratios of eight dispensable amino acids were combined with varying amounts of the ten essential acids. From these series of tests a satisfactory amino acid medium was developed.

The development of this medium has led to a diet containing only compounds of known chemical structure.

A casein medium and amino acid medium were used in studying the vitamin requirements of the pink bollworm. Seven vitamins were found to be essential for growth and development of the pink bollworm.

2. Mass Rearing Studies (McGough)

Some further work was done on methods of mass rearing pink bollworms for experimental use. A satisfactory method of mass rearing in the laboratory still has not been developed, owing to difficulties with fungi as previously reported. Cold storage of bolls infested with resting-stage larvae takes care of present laboratory needs and the heat technique, previously described in this report, makes it possible to drive the larvae from the seed. However, this does not alleviate the need for developing successful mass rearing techniques as an aid in future studies.

3. Feeding of Adults on Cotton Nectar (Clark and Lukefahr)

In previous work on the possibility of cotton nectar as a food for adults, it was assumed that the moths would feed in the field. Therefore, to substantiate this assumption, moths were released in a 4' x 4' x 6' cage containing cotton plants on which some of the nectar had been tagged with phosphorus^{32}. The results showed that during a 2-day period 38.4 percent of the moths were tagged through feeding on the nectar. This percentage cannot be used as a measure of the amount of feeding since many of the nectaries were not tagged.

Light Traps - ENT f3-17 (Glick)

Work with light traps as a means of insect control was discontinued after the investigations through 1955 showed that they were ineffective in controlling the insects on cotton, corn, and some vegetable crops. Light traps were used in studies involving recovery of moths tagged with radioactive phosphorus. In connection with moth flight studies in which airplane flights were made to collect insects in the upper air, light traps were operated at several localities to obtain an index of the surface population. In further development of light traps as a research tool, trap design features were evaluated in tests conducted in cooperation with the Farm Electrification Section, Agricultural Engineering Research Division.

Damage to Quality of Cotton Lint and Seed - ENT f3-19 (McGarr, Smith, and Richmond)

Cotton samples were obtained from insecticide experiments to determine the effects of the pink bollworm and other cotton insects, but have not as yet been analyzed.

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Vanderzant, E. S., Raymond Reiser, and E. E. Ivy. 1956. Methods for the mass rearing of the pink bollworm. Jour. Econ. Ent. 49(4):559-560.

Vanderzant, Erma S. 1957. Growth and reproduction of the pink bollworm on an amino acid medium. Jour. Econ. Ent. 50(2): 219-221.

Manuscripts in Process of Publication:

Tests with insecticides for control of the pink bollworm and the boll weevil in the Lower Rio Grande Valley in 1955 and 1956, R. L. McGarr.

Tests with insecticides for control of cotton insects in the Lower Rio Grande Valley, R. L. McGarr.

Mating and oviposition habits of the pink bollworm moth, Maurice Lukefahr and James Griffin.

Killing pink bollworms in cotton gin and oil mill products, O. T. Robertson, V. L. Stedronsky, and D. H. Currie.

Progress and problems of cotton insect control, K. P. Ewing.

The role of fatty acids in the development of the pink bollworm, Erma S. Vanderzant, Dundappa Kerur, and Raymond Reiser.

Cotton insect control in the western irrigated areas especially during the fruiting season, K. P. Ewing.

Papers Read at Meetings but Not Printed:

Preliminary studies on the use of nematode DD-136 as a control for some cotton insect pests, R. R. Sluss, ESA Meeting (Southwest Branch), San Antonio, Texas, March 11-12, 1957.

The effects of centrifugation of non-diapaused and diapaused pink bollworm larvae, Edgar W. Clark, ESA Meeting (Southwest Branch), San Antonio, Texas, March 11-12, 1957.

Collecting pink bollworm moths and other insects by airplane, Perry A. Glick, ESA Meeting (Southwest Branch), San Antonio, Texas, March 11-12, 1957.

Host plants of the pink bollworm, Ivan Shiller, ESA Meeting (Southwest Branch), San Antonio, Texas, March 11-12, 1957.

The amino acid requirements of the pink bollworm, Erma S. Vanderzant, ESA Meeting (Southwest Branch), San Antonio, Texas, March 11-12, 1957.

Toxicity tests with experimental compounds, A. L. Scales, L. J. Gorzycki, and G. T. Bottger, ESA Meeting (Southwest Branch) San Antonio, Texas, March 11-12, 1957.

Factors influencing pink bollworm carryover in central Texas, L. C. Fife, C. B. Cowan, Jr., and J. W. Davis, ESA Meeting (Southwest Branch), San Antonio, Texas, March 11-12, 1957.

PERMANENT PERSONNEL

Brownsville, Texas

Name	Title	Assignment
S. E. Jones	Station Leader	Coordinator, pink bollworm research.
A. J. Chapman	Entomologist	Assistant station leader.
L. W. Noble	Entomologist	Research planning and preparation of reports; leader, ecological research.
G. T. Bottger	Entomologist	Leader, toxicology research.
T. P. Cassidy	Entomologist	Leader, flax insect research and interpretation of pink bollworm research results.
E. W. Clark	Entomologist	Leader, physiological, biochemical, and isotope research.
P. A. Glick	Entomologist	Migration and light trap investigations.
J. A. Griffin[1/]	Entomologist	Insecticides and ecology.
W. L. Lowry	Entomologist	Toxicological research.
M. J. Lukefahr	Entomologist	Ecological studies.
R. L. McGarr	Entomologist	Leader, field insecticide research.
J. M. McGough	Entomologist	Pink bollworm parasites; attractants and repellents.
C. A. Richmond	Entomologist	Insecticide, physiological, and isotope research.
O. T. Robertson	Entomologist	Leader, cultural practices.
Ivan Shiller	Entomologist	Hibernation experiments; host plants.
R. R. Sluss	Entomologist	Insect pathology (Section of Beekeeping and Insect Pathology).
C. H. Tsao	Entomologist	Toxicological research.
A. L. Williamson	Entomologist	Physiological and biochemical research.
C. N. Husman	Equipment Specialist	Leader, development of research equipment and machinery for control of pink bollworm.
M. A. Taylor	Admin. Officer	Fiscal administrative.

1/ Assigned to Brownsville by State of Alabama.

Name	Title	Assignment
A. R. Galvan	Clerk	Fiscal administrative.
S. H. Robinson	Clerk-Typist	Clerical
E. S. Schunter	Secretary-Steno.	Clerical
F. W. Weeks	Clerk-Typist	Clerical
L. S. Bloom	Biological Aid	Toxicology studies.
J. E. Houghtaling	Biological Aid	Bioclimatic cabinet studies
J. C. Gonzalez	Laborer-Unalloc.	Labor as assigned.
D. Mayans	Laborer-Unalloc.	Labor as assigned.
Refugio Perez	Laborer-Unalloc.	Labor as assigned.
	College Station, Texas	
E. S. Vanderzant	Biochemist	Nutrition and biochemistry.
	Waco, Texas	
L. C. Fife	Entomologist	Hibernation and cultural control.