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Resistance of Cotton to Pink Bollworm Damage

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SUMMARY AND CONCLUSIONS

This bulletin gives results of studies conducted at College Station in 1954-55 to screen available species and varieties of cotton for resistance to pink bollworm damage.

Bolls of a Stoneville 2B x Gossypium tomentosum cross possessed a high degree of antibiosis to developing pink bollworm larvae. The mechanism of this resistance appeared to be a physiological response of the seed to insect injury. When seed were attacked, large masses of cells were proliferated which engulfed and killed many larvae.

Bolls of G. thurberi appeared to be less resistant to pink bollworm larvae than Stoneville 2B x G. tomentosum. However, results obtained for bolls of G. thurberi were distorted because of the extremely small boll size.

Hexaploid Z-64 bolls exhibited a lower degree of resistance to pink bollworm larvae than the two cottons mentioned above. The mechanism of this apparent resistance was not determined.

Morphological differences of the vegetative and fruiting parts of the cotton plant caused modification of the egg-laying habits of the pink bollworm moths. A tight-fitting calyx that was straight along the outer margin or had flared bracts or both, discouraged pink bollworm oviposition on cotton bolls. Pink bollworm moths were attracted to vegetative parts having heavy, coarse pubescence and leaves with heavy veins for oviposition.

Physical characteristics of the vegetative and fruiting parts of G. thurberi were such that few eggs were laid on plants of this cotton. This resulted in high percentages of the bolls escaping pink bollworm injury in all tests, even when other cottons were not available for oviposition. Thus, G. thurberi possessed resistance to the pink bollworm because it was not preferred by adults for oviposition.

The easiest and most logical approach to development of a cotton variety with resistance to pink bollworm damage would be modification of the structural characters of the cotton plant. 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 moths for oviposition than the fruiting parts. Presumably, the development of a cotton of this type is feasible since all the characteristics are found among various species of cotton.

A variety of cotton having these physical characteristics would exert several beneficial effects on pink bollworm control. Mortality from weather and other environmental factors should be much higher since the first instar larvae would have to migrate over the cotton plant in search of food. Eggs would be more accessible to predators and parasites on the vegetative parts than under the boll calyx, which should give increased natural control. Insecticides applied to the plants should be more effective since the larvae migrating in search of food would have a better chance of coming in contact with the chemicals deposited on the plants.

CONTENTS

Resistance of Cotton to Pink Bollworm Damage[1]

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THE PINK BOLLWORM, *Pectinophora gossypiella* (Saund.), is one of the most destructive pests of cotton and one of the six most important insects attacking cultivated crops. Entomologists and cotton farmers of the Unied States are particularly concerned about the pink bollworm because it is difficult to control by chemicals and continues to spread into the cotton areas to the north and east of Texas.

Effective chemical control is difficult because of the oviposition habits of the adult and the feeding habits of the larvae. Adults require only water to complete the functions of mating and oviposition. The preferred site for oviposition is between the calyx and carpel wall of the cotton boll where the eggs are well protected from predaceous and parasitic enemies. Many of the larvae hatching in these protected sites enter the boll immediately without moving about over exposed parts of the cotton plant. Larvae do not feed on the external parts of the plant or bolls. After entering the cotton boll, larvae are well protected from currently used insecticides.

Because of these habits of the insect, only contact insecticides are considered practical for chemical control. Since many larvae may not come in contact with the insecticide, control with chemicals usually is difficult. Therefore, cultural practices designed to lower overwintering larval populations are strongly recommended for the control of this pest.

A combination of cultural practices and chemical control measures has given moderate success. A possible supplement to these measures is the resistance of cottons to pink bollworm damage. Numerous authors in the past 40 years have mentioned cases in which cottons appeared to be resistant to attack by the pink bollworm. Most of these reports referred to wild or Asiatic cottons obtained from the general area in which the pink bollworm is believed to have originated. In most cases, these reports were made from casual field observations without conclusive supporting data.

The present study was designed to screen available species and varieties of cotton for resistance to pink bollworm damage according to two mechanisms of resistance as advanced by Painter (1951): (1) antibiosis or a tendency to affect adversely the biology of the insect by lengthening the life cycle, lowering fecundity, decreasing size or increasing mortality; (2) preference or nonpreference of the insect for certain species and varieties of cottons for oviposition or food. The influence of differences in calyxes, bracts and pubescence was particularly observed in the study of preference for oviposition.

A cotton possessing properties antibiotic to the larvae, or possessing morphological modifications that make vegetative parts more desirable for oviposition than fruiting parts, would aid existing methods of control of the pink bollworm.

REVIEW OF LITERATURE

General

Reports of the resistance of host plants to insect attack have been on record for over 100 years (Painter, 1951). One of the most effective and well-known examples as a means of insect control is the use of resistant rootstock to control the grape phylloxera, *Phylloxera vitifoliae* (Fitch), on grapes, Davidson (1921). Parnell (1935) and Parnell *et al.* (1949) reported excellent control of leafhoppers of the genus *Empoasca* on cotton in Africa by the use of resistant varieties. Only a few examples of such a high degree of host plant resistance to insect damage are known. Painter (1951) stated that the most important role of insect resistance in crop plants was to aid other control measures.

The term "insect resistance" is used in this study in the sense that Painter (1951) and Snelling (1941) used it. Painter classifies the causes of resistance as: (a) antibiosis—adverse effect of the plant on the biology of the insect; (b) preference — choice of certain plants by the insect for oviposition, food or shelter; and (c) tolerance —repair, recovery or ability of the plant to withstand insect attack. One, or a combination of any of the three, produces most cases of resistance.

While little is known about the cause of host plant resistance to insects, many workers have noted a relationship between physical characters of the host and insect resistance. Cunliffe and Hodges (1946) found that resistance of oats to *Oscinella frit* (L.) was connected with some factor of plant attractiveness which determined the extent of oviposition on the plants. Thrips

[1]Adapted from a dissertation in entomology submitted to the faculty of the Graduate School of the A&M College of Texas in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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resistance in onions was found in varieties with the thickest leaf epidermis, which apparently offered more mechanical resistance to feeding punctures (Peterson and Haber, 1942). Mumford (1931) reported that resistance of citrus to mealy bug attack was found in the thick-skinned varieties, which were more difficult for the insect mouthparts to penetrate.

Painter (1951) stated that it was doubtful whether differences in tissue hardness of varieties of one species of plant would be great enough to affect the degree of feeding by insects normally attacking that plant species.

Richardson (1925) pointed out that the physical character of plant surfaces in many cases may condition the oviposition response in insects. Thus, a plant variety that did not possess the necessary structural characters to stimulate the insect to oviposit could escape insect injury. Painter (1951) stated that various morphological differences found in plants elicit different responses from insects through mechanical stimuli. These mechanical stimuli are most likely to become a factor in host plant resistance to an insect by affecting the egg-laying response of the insect. Hairy leaves of corn were found by McColloch (1920) to contain more corn earworm eggs than smooth-leaved varieties. Other insects, such as roaches (Folsom, 1922) and *Drosophila* (Adolph, 1920), require a certain type of mechanical stimulus before oviposition occurs.

The bur seed fly, *Euaresta aequalis* Loew., was reported by Currie (1932) to be unable to oviposit in the bur of *Xanthium* sp. from which the recurved tips of the spines had been removed. Poos and Smith's (1931) studies of oviposition and nymphal development of *Empoasca fabae* (Harris) revealed that adults deposited eggs freely on all species of plants tested, but fewer nymphs developed on the plants with the most pubescence.

Jones *et al.* (1934) reported that the more open-type onion plant provided less suitable conditions for thrips development, resulting in lower populations and less damage to the host. Hinds (1906) reported that cell proliferation, a physiological response of the cotton boll to insect injury, caused the death of many boll weevils, *Anthonomus grandis* Boh., by mechanically crushing them.

Pink Bollworm

Marlatt (1918) advanced the theory that the pink bollworm originated in India and offered as supporting evidence the apparent resistance of native Indian cottons to this insect. Imported commercial cottons were much more susceptible to attack than the indigenous cottons. Husian *et al.* (1940) conducted experiments that supported Marlatt's theory of resistance of Old World cottons. In field plot and cage tests in the Punjab, he found significantly fewer bolls attacked and fewer larvae per boll in two Old World varieties of *Gossypium arboreum* L. than in three New World varieties of *G. hirsutum* L.

The pink bollworm was described by Saunders (1842) from specimens of the insect sent to him from India. The report accompanying these insects stated that native cotton sometimes was affected by the pest and added that imported Upland cotton was damaged severely when grown on light soils. Both Hunter (1926) and Durrant (1912) cited this report as evidence of resistance to pink bollworm damage in Old World cottons. Hilson (1925) stated that it was definitely known in Madras Presidency that the stem weevil, the spotted bollworm and possibly the pink bollworm showed a decided preference for *hirsutum* cottons over the indigenous species. Harland (1929) pointed out that workers on cotton frequently observed that the pink bollworm preferred New World to Old World cottons. He believed this preference was caused by a chemotropic response of the insect which resulted in the laying of more eggs on the plant species with the more attractive odor.

Wolcott (1927, 1928) found native cotton of Haiti much less attractive to pink bollworm than commercial varieties grown there. When commercial cotton was harvested, the insect attacked native cotton nearby, but resulting infestations steadily declined as the season advanced. Wolcott stated that although the cause of resistance was unknown, it seemed to be inherent in the cotton itself and not due to environmental factors. Audant *et al.* (1937) stated that one advantage of growing native cotton in Haiti was its resistance to pink bollworm. The natural protection proved so effective that negligible damage resulted while imported commercial cottons were forced out of production after the introduction of the pink bollworm in 1925. When only native cotton was grown commercially, the pink bollworm practically disappeared, infestations usually not exceeding 1 or 2 percent.

Fenton (1927) reported only a 3.85 percent infestation of *G. thurberi* Todaro bolls when grown near commercial varieties of cotton that had approximately 100 percent of the bolls infested by pink bollworm. No adults were observed to emerge from samples of these bolls when held overwinter.

Reports of Chapman (1937, 1938, 1941) on resistance of commercial varieties of cotton to pink bollworm damage indicated no resistance in the varieties studied. He stated, however, that the early-maturing varieties escaped much of the heavy, late-season pink bollworm damage.

Squire's (1939) experiments to determine the nature of resistance to pink bollworm in edible okra, *Hibiscus esculentus* L., indicated that 12 to 41 percent of the total mortality was attributable to slime engulfing the larvae. He compared the survival of pink bollworm larvae reared on

Gossypium trilobum (*DC*) Kearney and Sea Island cotton and found that approximately the same percentage of larvae entered each cotton but none developed on *G. trilobum*.

According to Knight (1944), Harland reported that *G. thurberi* was not attacked by the pink bollworm in Trinidad or Brazil. Knight further noted that *G. thurberi* planted at Shambat in the Anglo-Egyptian Sudan showed a complete absence of pink bollworms, although surrounding commercial varieties had a 97 percent infestation. He was of the opinion that *G. thurberi* was immune to pink bollworm attack under the conditions at Shambat. Crosses were made with Sakel (a variety of *G. barbadense*) to determine if the immunity could be transferred to New World cottons.

Several investigators attempted to breed cotton resistant to the bink bollworm at Shambat. Anson (1945) reported that *G. armourianum* Kearney appeared markedly resistant and included it in the breeding program. He crossed *G. armourianum* and Sakel and called the resulting hexaploid *G. armadense*. He considered this cotton a true species. The following year, Knight (1946) reported *G. armadense* to be free of pink bollworm infestation in the field. He suspected the resistance to be caused by the large supply of essential oils or resins, or both, found in oil glands over the plant and bolls. During the 1945-46 season, *G. thurberi* was crossed successfully with Sakel and the resulting hexaploid plants were called *G. thurbadense*. None of these plants showed any sign of resistance to pink bollworm attack, and Knight (1947) concluded that the resistance of *G. thurberi* was recessive.

Knight's (1948) report from Shambat for the 1946-47 season lists eight species of *Gossypium* that were surveyed during the season to determine the percentage of bolls infested by the pink bollworm. The results indicated that *G. thurberi, G. armourianum and G. somalense* (Günke) were highly resistant and *G. anomalum* Wawya and Peyvitsch less resistant to the pink bollworm.

During the 1947-48 season, *G. thurberi* and *G. armourianum* crosses with Sakel were tested in the field for pink bollworm resistance at Shambat. Knight (1949) reported that no appreciable resistance to pink bollworm was apparent in 1 acre of *G. thurberi* x Sakel crosses. He concluded that either the resistance could not manifest itself in a New World tetraploid cotton, or that not enough parents were used in the previous generation to insure reasonable certainty of including resistant plants. He considered the first possibility the more likely. Of the *G. armourianum* x Sakel crosses, two plants appeared resistant and were selected for further testing.

The breeding program at Shambat for resistance to pink bollworm was discontinued from 1947 to 1953 (Knight *et al.* 1953). The work from 1953 through 1955 consisted of selecting plants that appeared to suffer the least insect injury in the field and back-crossing them with commercial varieties (Knight *et al.* 1954 and Dark *et al.* 1955).

Few techniques have been developed for a study of this sort. Some workers, however, have conducted detailed studies in an attempt to determine if resistance to the pink bollworm existed in selected cottons. Squire (1939) described a technique in which each cotton boll was subjected to the same initial insect infestation by transferring freshly hatched larvae to the green bolls. He did not take into account differences in boll sizes when he recorded his results as larvae recovered per boll. Differences in boll size influence the number of larvae surviving in each boll. Brazzel and Martin (1955) showed that when cotton bolls were heavily infested with pink bollworms, many larvae were killed as they came in contact with each other. Thus, fewer larvae would be expected from smaller than from larger bolls when the initial infestation was the same. Husian *et al.* (1940) described a technique for small plot tests under cages for studies on resistance of cotton to pink bollworm. The technique employed in small plot tests in this study is similar to his.

Additional information on biology and host plants of the pink bollworm may be found in reports by Hunter (1926), Ohlendorf (1926), Loftin (1921), Ballou (1918) and Heinrich (1928).

PROCEDURE

General

Method of Obtaining Moths

Pink bollworm adults used for egg production and for infesting the caged plots were obtained from infested seed cotton collected during the fall of the previous season when most of the larvae were in the long cycle stage. The seed cotton was stored at approximately 40°F. and removed from storage and placed under pyramid-type emergence cages as adults were needed. The emergence cage was 3 feet square at the bottom and 2 feet high, with a collecting jar 2 inches in diameter which screwed into a holder at the top of the cage. A screen cone was placed in the mouth of the collecting jar with the concave portion of the cone pointing upward and provided with a 5-millimeter hole at the top to facilitate entrance of the moths into the jar. Moths entering the jar from the cage below were trapped. Moths would begin to emerge from the seed cotton in about 2 weeks if the material was kept moist and warm. The collection jars were inspected daily and moths removed. Carbon dioxide was used to immobilize the moths for handling. Emergence cages were placed in a shady area outside the laboratory during the summer and in

the greenhouse during the winter. The seed cotton was kept moist by spraying it with water at weekly intervals. Moths emerged from a cage for 6 to 8 weeks, then the spent cotton was replaced with fresh cotton from storage. A continuous supply of pink bollworm adults was maintained by using a battery of emergence cages and replacing the spent cotton in a different set of cages every 2 weeks.

Method of Obtaining Eggs

Pink bollworm adults collected from emergence cages were placed in a plywood box approximately 8 inches square which was coated inside with paraffin. A hole 4 inches in diameter in the top of the box was covered with 14 x 18 mesh galvanized screen wire. Another piece of 32 x 32 mesh plastic screen was placed over the coarser screen. A green cotton leaf was placed over these screens and held tight against them by a moistened towel. The moth would insert the abdomen through the screens and oviposit on the green cotton leaf.

Greenhouse Screening Experiment

Culture of Plants

Seed of 139 species and varieties of *Gossypium* were planted in 1-gallon tin cans filled with a suitable soil medium. Plants were thinned to one plant per pot and grown in the greenhouse throughout the 2-year period of the experiment. Five potted plants of each cotton were used to obtain the records desired. Deltapine 15 was used as a standard for comparison in all experiments. The origin of the cottons is given in Table 1. Classification is according to Hutchinson *et al.* (1947).

TABLE 1. RESULTS OF GREENHOUSE SCREENING EXPERIMENT FOR RESISTANCE OF COTTONS TO PINK BOLLWORM LARVAE AT COLLEGE STATION, 1954-55

Cotton	Total bolls	Mean boll weight in grams	Percent larvae		Larvae recovered per gram of boll weight	Comparison with Deltapine 15	Origin of cotton
			Entered bolls	Survived after entry			
Deltapine 15	307	13.7	71.6	71.8	.1892		United States
G. anomalum							Southwest Africa
G. arboreum							Asia & Africa
Garo Hill (a)	31	13.3	73.5	82.5	.2277		East Bengal & Assam, India
Garo Hill (b)	24	15.4	77.5	92.5	.2333		East Bengal & Assam, India
Nanking G-10	86	6.6	83.7	70.3	.4303	1	China
Neglectum (a)	35	4.4	65.7	66.1	.4897	1	India
Neglectum (b)	79	4.9	65.1	66.1	.4431	1	India
Okinawa	50	3.3	64.8	75.3	.7376	1	Okinawa
Sanguineum (a)	72	4.5	65.8	70.0	.5070	1	India
Sanguineum (b)	50	4.3	56.0	66.4	.4294	1	India
G. armourianum							Gulf of California
G. barbadense							South America
Darwinii	14	3.4	67.1	63.8	.6263	1	Galapagos Islands
Kidney cotton							Tropical South America
Pima	42	8.2	71.9	82.8	.3638	1	Americas
Crosses							
Diploid Z-783							College Station
Hexaploid Z-64	19	6.3	80.0	44.1	.2988		College Station
Hexaploid Z-66	52	3.8	67.3	61.1	.5371	1	College Station
Hexaploid Z-73							College Station
Hexaploid Z-77							College Station
Hexaploid Z-147	8	3.7	65.0	61.5	.5424		College Station
Hexaploid Z-721							College Station
Hexaploid Z-784							College Station
Stoneville 2B x G. tomentosum	79	4.7	58.9	24.7	.1564		College Station
Tetraploid 1	28	4.9	62.9	53.4	.3396	1	College Station
Tetraploid 2							College Station
Tetraploid 3							College Station
Tetraploid 4							College Station
Tetraploid 5	27	6.7	73.3	58.6	.3183	2	College Station
Tetraploid 6							College Station
G. gossypioides							Mexico
G. harknessii							Gulf of California
G. herbaceum							Asia & Africa
Kuljianum	79	2.8	67.6	74.2	.9087	1	Mongolia
Persicum	57	5.0	60.4	75.6	.4577	1	Persia
Wagad	44	6.4	69.5	64.7	.3543	2	Southwestern Asia
Wrightianum	29	6.7	66.9	68.0	.3385	2	India
G. hirsutum							North & South America
Baker 51	69	11.0	92.4	63.4	.2709		College Station
Frego bract	54	12.0	82.7	79.0	.2785	2	College Station
Lintless	27	9.8	77.0	80.8	.3185	1	College Station
MW-11	67	12.0	86.9	67.9	.2400		Guatemala
MW-147	41	18.3	88.0	71.4	.1693	3	Guatemala
MW-218	30	3.2	84.7	44.1	.5815	1	Mexico

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Cotton	Total bolls	Mean boll weight in grams	Percent larvae		Larvae recovered per gram of boll weight	Comparison with Deltapine 15	Origin of cotton
			Entered bolls	Survived after entry			
MW-255	23	2.6	62.6	45.8	.5574	2	Mexico
MW-269	26	16.8	65.4	72.9	.1418		Mexico
MW-298	19	1.2	67.8	26.2	.8676	2	Mexico
Pubescent	49	11.7	93.2	71.2	.2851		College Station
Punctatum	96	5.6	79.5	64.8	.4522	1	Arizona
SPHI-4	51	12.5	92.6	74.9	.2672		College Station
Texas 3	8	9.2	62.5	88.0	.2989		Mexico
Texas 16	12	14.1	83.3	84.0	.2488		Mexico
Texas 20	32	18.6	75.6	86.0	.1743		Mexico
Texas 21	39	21.2	72.8	81.7	.1400		Mexico
Texas 24	12	10.1	60.0	77.8	.2320	2	Mexico
Texas 29	21	15.8	82.9	83.9	.2196	2	Mexico
Texas 31	21	14.3	77.1	82.7	.2224	2	Mexico
Texas 32	38	17.8	75.3	86.0	.1815		Mexico
Texas 34	31	15.8	72.3	77.7	.1773		Mexico
Texas 35	18	14.0	71.1	84.4	.2144		Mexico
Texas 37	16	21.2	72.5	87.9	.1503		Mexico
Texas 40	37	13.8	77.3	69.9	.1952	2	Mexico
Texas 42	20	13.1	63.0	82.5	.1981		Mexico
Texas 43	43	17.3	76.7	79.4	.1759	2	Mexico
Texas 48	12	20.3	76.7	84.8	.1604		Mexico
Texas 49	27	13.3	69.6	77.7	.2029	2	Mexico
Texas 53	39	8.3	71.8	75.7	.3268	1	Mexico
Texas 55	24	7.2	74.2	78.7	.4060	1	Mexico
Texas 56	40	15.3	72.5	80.0	.1891	1	Mexico
Texas 61	15	8.7	78.7	79.7	.3217	1	Mexico
Texas 62	24	12.9	85.0	88.2	.2900	1	Mexico
Texas 63	23	11.1	81.7	78.7	.2907	1	Mexico
Texas 64	20	14.5	79.0	82.3	.2236	1	Mexico
Texas 67	26	14.7	66.2	75.6	.1701		Mexico
Texas 93	6	5.4	70.0	57.1	.3727	2	Guatemala
Texas 96							Guatemala
Texas 99	13	17.3	70.8	89.1	.1824		Guatemala
Texas 100	8	9.9	80.0	71.9	.2897		Guatemala
Texas 101	43	13.3	63.7	81.0	.1940		Guatemala
Texas 105	19	9.2	71.6	79.4	.3075	2	Guatemala
Texas 108	15	11.8	82.7	88.7	.3109	2	Mexico
Texas 109	28	10.3	67.1	87.2	.2846		Mexico
Texas 151	14	8.4	74.3	78.8	.3478		Guatemala
Texas 158	12	7.2	66.7	72.5	.3341	2	Guatemala
Texas 160	27	9.9	76.3	79.6	.3060	1	Mexico
Texas 161	21	11.5	56.2	83.1	.2029		Mexico
Texas 168	14	13.1	87.1	83.6	.2782		Guatemala
Texas 169	18	7.6	73.3	65.2	.3139	2	Guatemala
Texas 183	28	12.7	69.3	81.4	.2215	2	Mexico
Texas 195	12	11.3	65.0	82.1	.2362	2	Guatemala
Texas 197	11	9.1	47.3	69.2	.1805		Guatemala
Texas 198	16	7.9	52.5	81.0	.2690	2	Guatemala
Texas 200	15	10.8	69.3	80.8	.2585	2	Guatemala
Texas 203	29	9.6	64.1	81.7	.2727	1	Guatemala
Texas 204	20	10.3	60.0	85.0	.2467		Mexico
Texas 205	27	8.6	68.1	82.6	.3290	1	Mexico
Texas 206	17	11.7	71.8	86.9	.2675	2	Mexico
Texas 214	16	8.6	81.3	76.9	.3626	1	Guatemala
Texas 217	20	8.4	64.0	71.9	.2725		Guatemala
Texas 219	17	9.7	70.6	78.3	.2859	2	Guatemala
Texas 221	19	8.2	80.0	76.3	.3744	1	Guatemala
Texas 224	17	9.1	62.4	83.0	.2837	2	Mexico
Texas 225	28	9.1	75.0	75.2	.3110	1	Mexico
Texas 226	28	10.2	75.0	81.0	.2984	1	Mexico
Texas 239	18	9.0	72.2	78.5	.3133	1	Guatemala
Texas 240	23	6.8	74.8	72.1	.3972	1	Guatemala
Texas 242	20	11.7	79.0	79.7	.2691	1	Guatemala
Texas 243	22	10.8	76.4	81.0	.2861	1	Mexico
Texas 244	35	13.1	80.6	81.6	.2499		Mexico
Texas 245	12	9.5	65.0	79.5	.2729		Mexico
Texas 294	22	9.9	73.6	82.7	.3064		Mexico
Texas 366	33	6.8	57.0	84.0	.3510	1	Central America
Texas 382	29	17.8	71.0	72.8	.1455		College Station
Texas 384	32	17.2	91.3	79.5	.2113		Tahiti
Texas 389	23	0.5	11.3	53.8	.5932		Caribbean region
Texas 395	41	2.9	58.0	66.4	.6540	1	Arizona

TABLE 1. RESULTS OF GREENHOUSE SCREENING EXPERIMENT FOR RESISTANCE OF COTTONS TO PINK BOLLWORM LARVAE AT COLLEGE STATION, 1954-55 (continued)

Cotton	Total bolls	Mean boll weight in grams	Percent larvae		Larvae recovered per gram of boll weight	Comparison with Deltapine 15	Origin of cotton
			Entered bolls	Survived after entry			
Texas 398	39	3.9	64.1	78.4	.6389	[1]	Arizona
Texas 399	46	5.3	67.8	75.0	.4776	[1]	Arizona
Texas 402	31	5.3	67.7	80.0	.5147	[1]	Arizona
Texas 409	36	7.2	65.6	78.0	.3571	[1]	Arizona
Texas 420	42	12.4	75.2	71.5	.2176	[2]	United States
Texas 423	47	13.0	71.1	87.4	.2391	[1]	College Station
Texas 516	33	12.8	79.4	85.5	.2660		Belgian Congo
Texas 523	26	9.5	76.9	81.0	.3285	[2]	Belgian Congo
Texas 536							College Station
G. klotzschianum							Galapagos Islands
Davidsonii							Gulf of California
G. raimondii							Northern Peru
G. stocksii	14	0.3	22.9	31.3	1.2195	[2]	Southeastern Asia
G. sturtii							Australia
G. thurberi	82	0.9	31.7	22.3	.4096	[1]	Mexico & Arizona
G. tomentosum							Hawaiian Islands

[1]t test indicated that the number of larvae recovered per gram of boll weight was greater than for Deltapine 15 at the 1% level of significance.
[2]t test indicated that the number of larvae recovered per gram of boll weight was greater than for Deltapine 15 at the 5% level of significance.
[3]t test indicated that the number of larvae recovered per gram of boll weight was less than for Deltapine 15 at the 5% level of significance.

Cotton bolls were infested with pink bollworm eggs when 10 to 20 days of age. Infested bolls were removed from the plant and examined 10 days later when they were 20 to 30 days old. Blooms were tagged with a different colored tag during each 10-day period to identify bolls of proper age range for infestation with pink bollworm eggs or to collect them for examination. For example, all blooms were tagged daily with white tags from July 1 to 10. All bolls marked with white tags were 10 to 20 days old on July 20, at which time they were infested with pink bollworm eggs. On July 30, all white-tagged bolls were 20 to 30 days old and were collected for examination. By using tags of three colors and following this schedule of tagging, infesting and collecting, bolls on the plants of different age groups could be separated easily.

Infestation of Bolls

Each cotton boll in all tests was infested with five viable pink bollworm eggs when the boll was 10 to 20 days of age. Eggs deposited on a cotton leaf in the oviposition cage were removed with a moist camel hair brush and arranged in lots of five eggs on a sheet of paper marked off in 1 square centimeter sections. When sufficient lots of eggs had been collected, each lot was transferred to a boll on the cotton plant. Transfer of eggs to the cotton bolls was made with a moist camel hair brush. Egg masses were placed on the upper side of bolls in sutures near the apex. Eggs adhered to cotton bolls readily if sufficient moisture was applied to the bolls when the egg masses were transferred.

Eggs were allowed to develop for 2 days before they were used to infest bolls. Viable eggs could be identified easily by the reddish color of the developing embryo, as compared with the yellowish color of infertile eggs. Hatching of the egg usually occurred within 24 hours after transfer to the boll. An infestation level of five eggs per boll was selected because of the extremely small size of some cotton bolls.

Examination of Bolls

Infested bolls were removed from the growing cotton plant 10 days after eggs were applied and were examined for the number of entrance holes and larvae. Bolls at the time of examination were 20 to 30 days of age. This procedure allowed the pink bollworm larvae to develop in optimum-age bolls. Since bolls were not removed from the growing plant during the developmental period, larvae were subjected to natural conditions in the boll for development.

Because of the wide variety of cottons used and their unpredictable fruiting characteristics, it was impossible to obtain boll samples from each cotton during each 10-day period. To have comparable results, a sample was obtained from Deltapine 15 for each 10-day period. Only samples of Deltapine 15 collected at the same time as test samples were used in comparisons of each test cotton with the standard.

After bolls were collected, bracts and calyxes were removed by cutting smoothly across the base of each boll. The weight of each boll was recorded to the nearest 1/10 gram. Bolls were examined under a binocular microscope for the number of larval entrance holes evident on the outside of the boll and the number of larvae found inside each boll. The number of larvae

recovered per gram of boll weight from each cotton was calculated from the data obtained.

Field Plot Experiments

Two field plot experiments were conducted in 1954 and one in 1955. Experiment 1 in 1954 included *G. thurberi* and 41 varieties of *G. hirsutum*. Experiment 2 conducted the same year consisted of *G. thurberi* and 36 varieties of *G. hirsutum*. *Gossypium thurberi,* Pima (*G. barbadense*) and Deltapine 15 were included in the 1955 experiment.

Experimental Design

A randomized and replicated design was used in the experiments. Experiments 1 and 2 conducted during 1954 were each replicated four times. Each replicate consisted of one plant of each cotton randomized within a plot. The 1955 experiment was replicated five times with six plants of each cotton randomized in each replicate or plot.

Plots were two rows wide and 36 feet long, or 1/200 acre in size, and were inclosed by a 6 x 6 x 36-foot cage consisting of plastic screen stretched over a framework constructed of 1/2-inch galvanized iron pipe. The screen was regular 14 x 18 mesh which would exclude all pests except spider mites and aphids, and would confine pink bollworm moths released in the cage. Spider mites and aphids were controlled by monthly foliage applications of schradan.

Culture of Plants

Seed of the different cottons were treated with Ceresan and were germinated in the greenhouse in 5-ounce paper drinking cups filled with a mixture of 50 percent fine gravel and 50 percent humus soil. The soil mixture was kept moist by watering daily. Plants were transferred to the field after reaching the two to four-leaf stage.

The cottons were planted in the greenhouse about May 15 and were transferred to plots in the field during the first week of June. Transplanting was done by tearing away the paper cup and setting the plant, with the soil mass on the roots, into properly spaced holes in the plots. Spacing of plants was 18 to 20 inches in the row.

Blooms were tagged in these experiments in the same manner as described for the greenhouse experiment. Tagging of blooms was started in 1954 when the first blooms appeared. Since some varieties bloomed earlier than others, all cottons were not represented in each boll collection. Therefore, the procedure was modified slightly in the 1955 experiment. All squares were removed at weekly intervals from earlier fruiting cottons until squares were present on all the cottons. Then the plants were allowed to bloom and the blooms tagged in the usual manner.

Infestation of Plots

Pink bollworm populations inside caged plots were controlled by periodic introduction of moths. Approximately 150 moths were introduced into each cage at 10-day intervals. No attempt was made to sex moths since the sex ratio was approximately 50-50.

Fenton and Owen (1953) found that the preoviposition period of the pink bollworm was approximately 3 days. Eighty-two to 94 percent of the eggs were laid on bolls when they were available. Also, the greatest total egg deposition occurred the first night of oviposition and oviposition usually ceased in 7 to 10 days. Therefore, the first moth releases were made in the cages 3 days before the oldest bolls were 20 days of age to allow for the 3-day preoviposition period of the insect. When the moths started laying eggs, a crop of bolls ranging from 10 to 20 days of age was available for oviposition. The level of pink bollworm infestation selected was heavy, but this was considered necessary to prevent any cotton bolls from accidentally escaping infestation. The cottons set bolls throughout the season.

Examination of Bolls

Bolls were collected when 20 to 30 days old and were examined in the same manner described for the greenhouse experiment. Boll collections were made at 10-day intervals from August 10 through October 20 in experiment 1, and from August 14 through October 14 in experiment 2 during 1954. In 1955, boll samples were collected on September 20 and 30 and October 10.

Oviposition Experiments

Experimental Design

Combinations of selected cottons with various modifications of bracts, calyxes, pubescence and leaf types were randomly planted in 1/200-acre plots in the field. The plots were caged in the same manner as the field plot test. Each test included only one caged replicate.

Two tests were conducted during 1954. *G. thurberi* and Deltapine 15 were included in test 1, and *G. thurberi* only in test 2. Seven experiments were conducted during 1955. The cottons included in each were: test 1—*G. herbaceum,* Frego bract and Deltapine 15; tests 2 and 3—Pima and Deltapine 15; test 4—Pima, Texas 536 and Deltapine 15; tests 5 and 6—Pima, *G. thurberi* and Deltapine 15; and test 7—*G. thurberi* with bolls present, Pima and Deltapine 15 with all bolls removed.

Characteristics of Cottons

Cottons included in these experiments and the structural characteristics of each are described following. Deltapine 15 had normal foliaceous bracts which were serrate almost half of their length. The outer margin of the calyx was con-

voluted with a total of five or six elongate tips occurring around the boll. A moderate amount of pubescence was present on the vegetative parts, with the most found in the growing terminals.

Pima had very large foliaceous bracts which completely covered the boll, with relatively shallow serrations along the distal edges. The calyx was membranous and straight along the outer edge, fitting tightly against the carpel wall. The leaves were larger and had heavier midribs than Deltapine 15. A moderate number of stiff leaf hairs were on the younger leaves.

G. thurberi had narrow, stiff, spike-like, flared bracts. The calyx was fleshy and straight along the distal edge, fitting tightly against the carpel wall. The midribs of the leaves were weak and the plant was almost glabrous.

G. herbaceum was similar to Deltapine 15 except that the bracts flared widely, exposing the entire cotton boll.

Frego bract was a mutant of *G. hirsutum* that had distorted, twisted, slightly narrowed and elongate bracts.

Texas 536, commonly called Extreme Round Leaf, had narrow bracts, 5 to 7 millimeters in width, which gave the boll the appearance of being almost bare. The leaves narrowed at the junction of the petiole and blade and looked much like cotton suffering from 2,4-D damage.

G. thurberi, G. herbaceum, Frego bract and Texas 536 were planted in paper cups in the greenhouse, as described for the field plot experiments. These cottons were transplanted to the plots in the field after reaching the four-leaf stage. Pima and Deltapine 15 seed were planted directly into the plots in the field.

Infestation of Plots

Approximately 150 moths were introduced into each caged plot when the cottons had bolls of the desired age. The oldest bolls in experiment 1 of 1954 were 3 weeks old and 4 weeks old in experiment 2 when moths were introduced into the cages. Experiments 1 through 4 of 1955 contained bolls 3 weeks old and experiments 5, 6 and 7 had bolls older than 3 weeks when moths were introduced.

Cotton plants in the plots were exposed to the pink bollworm moths for 5 days before examination. This allowed for a 3-day preoviposition period and 2 days of maximum oviposition. An infestation level of 150 moths to 1/200 acre was high, but was used to insure that no cotton bolls escaped oviposition accidentally.

Examination of Bolls

Five days after the cottons were exposed to pink bollworm adults, 5 to 10 plants of each cotton were selected for examination for eggs. All plants collected for examination had approximately the same amount of vegetative growth. The vegetative sites examined for eggs were terminals, leaves and the axils of stems and leaves. Squares and bolls below the bracts around the nectaries, inside the bracts and under the calyx were examined for eggs.

Attempts were made to modify the bracts and calyx of Deltapine 15 by cutting and trimming them to determine how these modifications might affect the oviposition habits of the pink bollworm moths. The bracts were cut away completely but the resulting rough, pitted depression formed at the site of the wound attracted moths for oviposition. The convoluted tips were trimmed from the calyx to make it straight along the outer edge. However, the calyx curled and split where it had been cut, resulting in many eggs being deposited in these locations. Apparently the distortions afforded the necessary stimuli to induce oviposition and the moths were attracted to these distorted locations. Since the desired modifications could not be produced artificially, the technique was discontinued.

RESULTS AND DISCUSSION

Greenhouse Experiment

Results of a 2-year greenhouse experiment designed to screen cottons for antibiotic action on pink bollworm larvae indicated the possible resistance of several cottons. The data were used in several types of tests for significance in evaluating the results of this experiment. Cottons that appeared to be resistant in one type of test and not resistant in another were eliminated.

Larval behavior of the insect before and after entry into the cotton boll should be considered in an evaluation of the results of this experiment. Pink bollworm larvae are antagonistic toward each other and many migrate away from cotton fruits when the larvae are crowded (Brazzel and Martin, 1955). This reaction to crowding could explain the relatively low percentages of larvae that entered the small-boll cottons with mean boll weights below 2 grams. The same authors reported that pink bollworm larvae may kill each other inside the cotton boll. Thus, the high mortality inside the small-boll cottons could be due to the cannibalistic habit of the larvae. This would lower the percentage of survival of the larvae that entered the small bolls.

The use of five eggs to infest cotton bolls, regardless of the size of the boll, tended to distort the data. Results obtained with five eggs placed on a small boll of *G. stocksii,* which averaged 0.3 gram in weight, would not be valid for comparison with the results obtained with five eggs applied to a boll of Texas 21 with a mean boll weight of 21.2 grams. For example, *G. thurberi* had a mean boll weight of 0.9 gram. The mean boll weight of Deltapine 15 was 13.7 grams. If the pink boll-

worm infestation were based on the number of larvae per gram of boll weight, the infestation of *G. thurberi* bolls was approximately 15 times greater than on Deltapine 15 bolls.

It was thought, however, that the techniques employed in this experiment were acceptable, even with these obvious sources of error. The experimental error affected the extremely small-boll cottons most; however, only four cottons were included that could be considered as having extremely small bolls (with a mean boll weight of less than 2 grams). The purpose of the various tests for resistance was to test the data thoroughly in view of the experimental error. It was thought that this error could be adjusted best when the experimental design consisted of a constant level of infestation for all cottons, since the boll size of the different cottons was not known. Thus, the limitations of each test were considered when evaluations of the results for significance were made.

Adequate samples of bolls were obtained from 108 of the cottons tested, which included varieties of *G. hirsutum, G. arboreum, G. barbadense, G. herbaceum, G. stocksii, G. thurberi* and various crosses. The greenhouse experiment was designed and the data collected in a manner that would permit comparisons of the number of larvae recovered per gram of boll weight of each cotton.

Significantly more larvae per gram of boll weight were recovered from 68 of the cottons than from Deltapine 15. In 41 of these cottons, the differences were highly significant. MW-147 contained significantly fewer larvae than Deltapine 15 and was the only cotton that appeared to be resistant by this test for significance. However, the position of this cotton in relation to the regression line in Figure 1 indicated no resistance.

Results obtained for the mean boll weights and number of larvae recovered per gram of boll weight, Table 1, indicated a correlation between these two values. As the mean boll weight increased, the number of larvae recovered per gram of boll weight decreased. The curvilinear regression of larvae recovered per gram of boll weight on mean boll weights is shown in Figure 1. The position below the regression line of *G. thurberi*, Texas 389 and a cross of Stoneville 2B x *G. tomentosum* indicated resistance to pink bollworm attack. Two of these cottons, *G. thurberi* and Texas 389, had extremely small bolls which averaged less than 2 grams in weight. *Gossypium stocksii* and MW-298 also had bolls that averaged less than 2 grams in weight, but they plotted well above the regression line in Figure 1, indicating a high degree of susceptibility to pink bollworm damage.

The large differences in the number of larvae recovered per gram of boll weight for the four varieties with mean boll weights of less than 2 grams indicated that greater variation existed in the boll samples of the small-boll than in the large-boll cottons. A test of homogeneity of variances of the number of larvae recovered per gram of boll weight from individual bolls showed highly significant differences between these four cottons and Deltapine 15. There was no significant difference in the variation of number of larvae recovered per gram of boll weight from individual bolls of *G. thurberi*, Texas 389 and MW-298, which had mean boll weights of 0.9, 0.5 and 1.2 grams, respectively. However, there was a highly significant difference between the variation of individual boll records of *G. stocksii*, with a mean boll weight of 0.3 gram, and the variation of the other three small-boll cottons. Results of these tests indicated that the variation in number of larvae recovered per gram of boll weight among individual bolls of small-boll cottons, particularly those with a mean boll weight below 2 grams, was significantly greater than for large-boll ones, such as Deltapine 15. Thus, results obtained under conditions of this experiment for these small-boll cottons were variable and not as reliable as those for large-boll cottons.

A similar test of the Stoneville 2B x *G. tomentosum* cross, with a mean boll weight of 4.7 grams, and Deltapine 15 revealed no significant differences in variation of number of larvae recovered per gram of boll weight among individual bolls at the 1 percent level of significance. This indicated that results obtained from bolls as large as those of the Stoneville 2B x *G. tomentosum* cross or larger would not be affected by the variation in number of larvae recovered from individual bolls. Thus, the results would be more reliable.

A comparison of the number of larvae that entered the cotton bolls with the number that survived has been used by some workers as a measurement of resistance. Percentages of larvae that entered the boll and survived are shown in Table 1. The percentage of survival of larvae that entered bolls was plotted against the mean boll weight of the cottons in Figure 2. Lower percentages of larvae survived in *G. thurberi, G. stocksii*, Texas 389 and the Stoneville 2B x *G. tomentosum* cross. This is an indication of resistance by these four cottons. However, *G. stocksii* and Texas 389 appeared to be highly susceptible to pink bollworm damage in the test for resistance shown in Figure 1. *G. thurberi* and the Stoneville 2B x *G. tomentosum* cross appeared to be resistant in tests shown in Figures 1 and 2.

The cross of Stoneville 2B x *G. tomentosum* was the most resistant cotton of the group tested. However, there was no significant difference in the number of larvae recovered per gram of boll weight for this cotton and Deltapine 15 when tested by group comparisons. Results of the

group comparisons of each cotton with Deltapine 15, indicated that most of the cottons with mean boll weights ranging up to 8 grams were significantly more susceptible to the pink bollworm than Deltapine 15. The Stoneville 2B x *G. tomentosum* cross had a mean boll weight of 4.7 grams, yet the difference in number of larvae recovered per gram of boll weight was not significant. Thus, this cotton departed from the pattern set by other cottons with a similar boll size enough to indicate resistance by this test for significance.

The apparent resistance of the Stoneville 2B x *G. tomentosum* cross seemed to be caused by cell proliferation in the cottonseed. Results showed that a high percentage of larvae entered the cotton bolls, but the percentage of survival was low. There was a slight amount of cell proliferation in the carpel wall where the larvae entered but not enough to kill many larvae. Most of the larvae seemed to survive until they reached the cottonseed. The membranous seed coat prevented first instar larvae from entering the seed directly; therefore, they fed on the outside of the seed until they found a suitable place to enter. Many of the larvae were engulfed by large, clear, granular cells and were killed as they fed over the outer portion of the seed. The cell proliferation seemed to be initiated by insect injury to the seed. Rarely would proliferation prevent the formation of normal lint and seed, even when the cotton boll was attacked by several larvae. Most of the larvae recovered from this cotton were taken from older bolls that were not growing rapidly and in which cell proliferation was not so pronounced.

G. thurberi appeared to be resistant in this experiment. The percentage survival of larvae that entered the bolls was low, Figure 2, and the value for larvae recovered per gram of boll weight plotted against mean boll weight was well below the regression line, Figure 1. However, the results of the group comparison of this cotton with Deltapine 15, Table 1, indicated that significantly more larvae were recovered per gram of boll weight from *G. thurberi.* As mentioned earlier, this cotton had a mean boll weight of 0.9 gram and was included in the group of cottons that had highly significant differences in the variation among individual boll samples. Also, there was no lint on the seed of this cotton and the larvae moved about freely inside the boll. Thus, cannibalism may have been important in reducing larval populations in these small bolls. This cotton was considered to have some antibiotic effect on pink bollworm larvae, but not as much as the Stoneville 2B x *G. tomentosum* cross.

The cause of the apparent resistance of *G. thurberi* to pink bollworm also seemed to be cell proliferation. The percentage of larvae that entered the bolls was low, indicating that they may have been repelled by the cotton boll in some manner. However, low percentages of larvae entered the other small-boll cottons and this could be explained by the small boll size and the antagonistic tendency of the larvae. Also, there was a low percentage of survival of larvae that entered *G. thurberi* bolls. The young, fast-growing bolls would respond to insect injury by

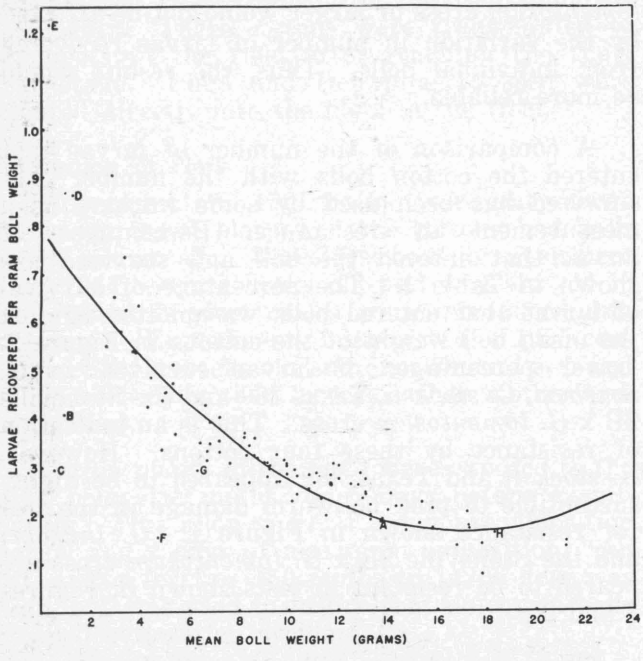

Figure 1. Regression of number of larvae recovered per gram of boll weight on mean boll weight for 108 cottons in greenhouse screening experiment for resistance to pink bollworm damage, College Station, Texas, 1954-55: (A) Deltapine 15, (B) *G. thurberi,* (C) Texas 389, (D) MW-298, (E) G. *stocksii,* (F) Stoneville 2B x *G. tomentosum,* (G) Hexaploid Z-64, (H) MW-147.

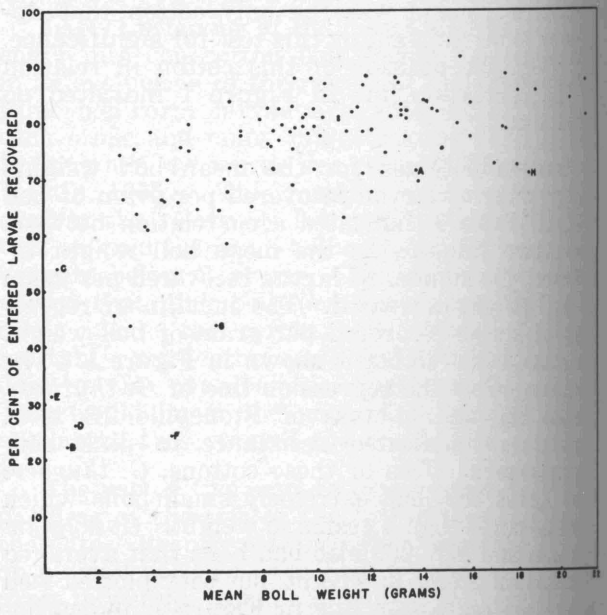

Figure 2. Percentage of survival of larvae that entered bolls on mean boll weight for 108 cottons in greenhouse screening experiment for resistance to pink bollworm damage, College Station, Texas, 1954-55: (A) Deltapine 15, (B) *G. thurberi,* (C) Texas 389, (D) MW-298, (E) *G. stocksii,* (F) Stoneville 2B x *G. tomentosum,* (G) Hexaploid Z-64, (H) MW-147.

proliferating great masses of granular tissue. This proliferation of cells seemed to come from the carpel walls where larvae entered and often would fill the entire locule of the boll. Pink bollworm larvae were trapped in this mass of tissue and many were killed, apparently by mechanical pressure. The proliferated tissue was not toxic to the larvae because larvae were reared successfully in containers using this material for food. Most larvae recovered from this cotton were found in bolls about 4 weeks old that did not proliferate as much as younger bolls. An undesirable aspect of this phenomenon in *G. thurberi* was that the proliferation that killed pink bollworm larvae usually destroyed the locule attacked, and the entire boll in many cases.

Table 1 and Figures 1 and 2 indicate that Hexaploid Z-64 possibly was resistant to pink bollworm damage. Only 44.1 percent of the larvae that entered bolls survived and it was below the regression line plotted in Figure 1. While the degree of resistance in either test did not appear to be outstanding, it was consistent.

Field Plot Experiments

The criteria used to test the cottons for resistance to pink bollworm in the field plot experiments were the number of larvae recovered per gram of boll weight, which was a test for antibiotic effects on larvae, and the number of larval entrance holes found in bolls, to test for preference. Bolls that had no larval entrance holes were considered as escaped bolls and indicated nonpreference for oviposition by the adult.

The number of larvae recovered per gram of boll weight was considered a more valid criterion of resistance than the mean number of larvae recovered per cotton boll from each cotton. Results, Tables 2, 3 and 4, show that the number of larvae recovered per boll definitely depended on boll size. Therefore, if the number of larvae recovered per boll was used as a measurement of resistance, the small-boll cottons would appear to be more resistant and large-boll varieties more susceptible than Deltapine 15. The use of the

TABLE 2. RESULTS OF CAGED FIELD PLOT EXPERIMENT 1 FOR RESISTANCE OF 33 VARIETIES OF COTTONS TO PINK BOLLWORM DAMAGE AT COLLEGE STATION, 1954

Cotton	Total bolls	Entrance holes per boll	Larvae recovered per boll	Mean boll weight in grams	Larvae recovered per gram boll wt.	Bolls escaped	
						No. bolls	Percent[1]
Deltapine 15[2]	117	12.8	6.0	12.7	.4921	5	8.54
G. thurberi	298	2.3	0.3	0.8	.3888	65	31.48
G. hirsutum							
Texas 3	60	24.4	9.4	11.7	.8084	0	0
Texas 20	69	18.2	8.4	18.5	.4905	0	0
Texas 21	88	20.3	8.3	16.4	.5293	0	0
Texas 24	72	19.0	8.6	11.6	.7781	1	2.27
Texas 29	126	20.2	9.4	17.4	.5420	1	2.03
Texas 31	26	27.2	12.3	25.4	.6451	0	0
Texas 32	105	14.4	7.2	14.3	.5130	6	13.87
Texas 34	106	15.1	7.3	18.0	.4049	3	7.80
Texas 35	92	22.3	9.9	17.9	.5519	1	2.96
Texas 37	19	30.4	13.6	23.3	.5270	0	0
Texas 40	87	11.7	5.1	14.3	.3731	6	10.30
Texas 42	44	9.3	4.8	15.7	.2929	3	6.62
Texas 43	109	18.6	8.4	17.5	.5056	3	3.92
Texas 49	87	20.8	9.0	12.5	.6971	0	0
Texas 53	106	16.5	7.8	10.9	.6569	0	0
Texas 56	108	17.3	8.0	16.5	.5341	2	3.13
Texas 61	22	16.5	6.5	11.2	.4488	0	0
Texas 62	61	14.1	6.1	8.2	.7054	0	0
Texas 63	121	17.5	8.0	13.9	.5923	0	0
Texas 64	133	17.8	8.1	12.6	.6544	4	5.86
Texas 67	99	19.0	8.4	15.7	.4960	1	2.99
Texas 99	43	23.0	9.8	18.1	.5813	0	0
Texas 100	40	19.8	8.1	11.1	.6448	0	0
Texas 101	73	10.3	4.7	11.9	.3803	4	10.89
Texas 105	62	24.3	8.2	13.4	.7390	1	2.61
Texas 108	37	18.3	7.8	11.1	.7056	1	4.03
Texas 109	87	21.6	9.6	11.6	.8360	0	0
Texas 160	77	19.4	8.2	10.6	.7709	0	0
Texas 161	25	18.1	7.4	11.8	.8246	0	0
Texas 168	82	17.1	7.2	11.6	.6265	1	3.42
Texas 183	119	19.2	8.7	13.5	.6835	2	3.26
L.S.D. at 5% level					.1868		8.54
L.S.D. at 1% level					.2474		11.32

[1]Percentages converted to angles.
[2]Standard cotton.

number of larvae recovered per gram of boll weight resulted in data which were comparable for all cottons.

Adequate bolls for inclusion in the analyses were obtained in experiment 1 for 32 varieties of *G. hirsutum* and *G. thurberi.* The identity of the cottons and results obtained are shown in Table 2. Analysis of the data indicated that significant differences existed between Deltapine 15 and 11 of the cottons in the number of larvae recovered per gram of boll weight. Significantly more larvae were recovered from 10 of these 11 cottons than from Deltapine 15 and in 5 of these cottons the differences were highly significant. This indicated that these cottons were more susceptible than Deltapine 15 to pink bollworm attack. Texas 42 was the only cotton which contained significantly fewer larvae per gram of boll weight than Deltapine 15.

This significant difference in the case of Texas 42 seemed to indicate resistance of an antibiotic nature until the data presented in Table 2 were examined carefully. Texas 42 had a mean boll weight of 15.7 grams and an average of 9.3 entrance holes per boll was recorded. The respective values for Deltapine 15 were 12.7 grams and 12.8 entrance holes. The trend in average number of entrance holes to mean boll weight shown in Table 2 was for the number of entrance holes to increase as the boll weight increased. Texas 42 contained about half the number of entrance holes that would be expected for a mean boll weight of 15.7 grams. This could have been because the adults did not prefer this cotton for oviposition or because many larvae hatching on the bolls were repelled in some manner by the cotton and did not attempt to enter the bolls. Results obtained for Texas 42 in the greenhouse experiment, Table 1, support the hypothesis that the apparent resistance exhibited by this cotton was caused by nonpreference of adults for oviposition.

A highly significant number of bolls of *G. thurberi* escaped pink bollworm damage, Table 2. This indicated that bolls of this cotton either repelled the larvae or that eggs were not laid on the bolls by the adults.

Cottons for which adequate numbers of bolls were collected and results obtained in experiment 2 are shown in Table 3. Three of the cottons contained significantly more larvae per gram of boll weight than Deltapine 15, two at the 1 percent level of significance and one at the 5 percent level. *G. thurberi* contained fewer larvae per gram of boll weight than Deltapine 15 and the difference was highly significant. There was no significant difference in the number of larvae recovered per gram of boll weight from *G. thurberi* and Deltapine 15 in experiment 1. A highly significant number of *G. thurberi* bolls escaped pink bollworm injury in this experiment, as in experiment 1.

TABLE 3. RESULTS OF CAGED FIELD PLOT EXPERIMENT 2 FOR RESISTANCE OF 25 VARIETIES OF COTTONS TO PINK BOLLWORM DAMAGE AT COLLEGE STATION, 1954

Cotton	Total bolls	Entrance holes per boll	Larvae recovered per boll	Mean boll weight in grams	Larvae recovered per gram boll wt.	Bolls escaped	
						No. bolls	Percent[1]
Deltapine 15[2]	88	21.5	8.8	13.8	.6295	1	2.81
G. thurberi	180	1.1	0.2	1.0	.1890	76	38.39
G. hirsutum							
Texas 195	23	15.7	6.8	10.4	.6281	0	0
Texas 203	33	10.7	5.6	10.5	.3931	0	0
Texas 204	79	14.1	7.1	11.1	.6800	5	9.46
Texas 205	88	13.5	6.0	9.1	.5494	3	16.94
Texas 206	85	15.7	7.3	10.5	.5899	1	2.08
Texas 225	55	14.1	6.7	10.6	.6583	1	2.41
Texas 226	61	16.7	8.4	13.0	.7030	1	2.50
Texas 242	52	15.9	7.6	12.1	.6783	1	4.19
Texas 243	44	14.2	6.3	10.8	.6091	1	3.52
Texas 245	51	12.5	5.9	10.7	.5614	0	0
Texas 294	88	14.9	6.1	9.4	.6753	3	7.02
Texas 366	16	10.3	3.1	4.6	.7009	2	13.53
Texas 382	87	23.3	10.8	17.2	.6819	0	0
Texas 384	68	23.4	11.8	19.4	.6194	0	0
Texas 395	130	6.1	2.2	3.1	.6966	11	15.18
Texas 398	83	7.9	3.9	4.1	.9388	2	4.03
Texas 399	83	10.9	5.3	5.3	1.9531	4	5.90
Texas 402	76	9.4	4.7	4.6	1.0075	1	3.86
Texas 409	139	15.2	6.7	7.4	.8851	1	3.06
Texas 420	118	20.6	9.3	13.6	.6804	0	0
Texas 423	59	19.2	8.9	12.7	.7453	2	8.84
Texas 516	92	19.7	7.5	9.1	.7622	2	5.60
Texas 523	112	18.0	8.1	10.5	.8802	0	0
L.S.D. at 5% level					.2652		12.84
L.S.D. at 1% level					.3522		17.07

[1]Percentages converted to angles.
[2]Standard cotton.

The experiment conducted in 1955 was designed to obtain additional data for *G. thurberi.* The cottons included were *G. thurberi,* Deltapine 15 and Pima (*G. barbadense*). More plants of each cotton were included in each replicate and the pink bollworm infestation was higher than during 1954. This procedure was followed to obtain larger, more representative boll samples and insure that *G. thurberi* bolls were not accidentally escaping pink bollworm injury. Results obtained are shown in Table 4. Analysis of the data indicated no significant differences in the number of larvae recovered per gram of boll weight. However, in this experiment, as in both experiments of the previous year, a highly significant number of *G. thurberi* bolls escaped pink bollworm injury.

The results obtained for the number of larvae recovered per gram of boll weight for *G. thurberi* may be explained to some extent by the difference in mean number of larval entrance holes per boll for *G. thurberi* for the three experiments. It was assumed that the number of larval entrance holes per boll was an indication of the level of larval infestation to which the bolls were exposed. The average number of larval entrance holes per boll for *G. thurberi* was 1.1, 2.3 and 3.1 for experiments 2 and 1 of 1954 and the 1955 experiment, respectively. The number of larvae recovered per gram of boll weight in the same order of experiments was 0.1890, 0.3888 and 0.6883. Thus, as the level of larval infestation on the bolls increased, the number of larvae recovered per gram of boll weight increased. The only apparent conclusion to make from these data was that the *G. thurberi* bolls in experiment 2 of 1954 were not infested to the same degree as the other cottons. There were no significant differences in the number of larvae recovered per gram of boll weight from *G. thurberi* in the other two experiments when the bolls were exposed to higher populations of pink bollworm larvae.

The most significant information obtained from the field plot experiments conducted during 1954 and 1955 was that a highly significant number of *G. thurberi* bolls escaped pink bollworm damage in all experiments. This is particularly outstanding in view of the conditions under which the 1955 experiment was conducted. The insect infestation was increased from 150 to 200 moths per 1/200-acre plot. The ratio of *G. thurberi* plants to other cottons in the 1954 experiments was 1 to 35 or 40. In 1955, there was one *G. thurberi* plant for every two plants of other cottons. This procedure resulted in practically forcing the insect to *G. thurberi.* Yet, highly significant numbers of bolls escaped insect injury. The indicated resistance in *G. thurberi* appeared to be the result of nonpreference of the adults for oviposition.

Two possible explanations of why *G. thurberi* bolls escaped pink bollworm damage were: the eggs were laid on the bolls or vegetative parts, but the larvae were repelled by the fruit for some reason and migrated from it, or the bolls and vegetative parts of *G. thurberi* were not preferred for oviposition. The data of the greenhouse screening experiment showed that 31.7 percent of the larvae placed on bolls entered the bolls. This indicated that extensive migration from the *G. thurberi* bolls occurred, but most of the bolls contained at least one larval entrance hole. This extensive larval migration is normal for the small-boll cottons such as *G. thurberi.* These facts do not support the theory that *G. thurberi* bolls repelled pink bollworm larvae.

There was more evidence that supported the hypothesis that *G. thurberi* bolls and vegetative parts were not preferred for oviposition by the adult and, as a result, the bolls of this cotton contained lower levels of larval infestation than the other cottons in the caged plots. Tables 2, 3 and 4 show that as the average number of larval entrance holes per boll and the larvae recorded per gram of boll weight for *G. thurberi* increased, the percentage of bolls that escaped injury decreased. It was assumed that the reason the bolls escaped injury was that the moths did not oviposit as readily on *G. thurberi* as on the other cottons. Thus, nonpreference may have been the cause of the apparent resistance of *G. thurberi* under the conditions of the field plot experiments.

A significant number of bolls of Texas 204 escaped pink bollworm damage in experiment 2, Table 3. However, the third replicate of the experiment produced only two bolls of Texas 204 and one of them escaped pink bollworm injury. Data from this small sample of bolls perverted the results when averaged with data from the other replicates; therefore, the indicated significance for Texas 204 was disregarded.

TABLE 4. RESULTS OF CAGED FIELD PLOT EXPERIMENT FOR RESISTANCE OF PIMA AND G. THURBERI TO PINK BOLLWORM DAMAGE AT COLLEGE STATION, 1955

Cotton	Total bolls	Entrance holes per boll	Larvae recovered per boll	Mean boll weight in grams	Larvae recovered per gram boll wt.	Bolls escaped	
						No. bolls	Percent[1]
Deltapine 15[2]	233	24.1	8.7	15.3	.5678	1	2.13
Pima	262	27.7	8.1	13.2	.6406	0	0
G. thurberi	642	3.1	0.6	1.0	.6883	51	16.21
L.S.D. at 1% level							10.43

[1]Percentages converted to angles.
[2]Standard cotton.

Another point of interest illustrated in both the greenhouse screening experiment and experiment 2 of 1954 was the apparent high susceptibility of the Hopi cottons to pink bollworm attack. These cottons were listed in Tables 1 and 3 as Texas 395, 398, 399, 402 and 409. The mean boll weight ranged from 2.9 to 7.2 grams. Survival of larvae entering the bolls ranged from 66.4 to 80.0 percent. These are relatively high values for such small-boll cottons. Larval recovery per gram of boll weight for Texas 402 in the field plot experiment, with a mean boll weight of 4.6 grams, was 1.0075. This is an extremely high value for larval recovery and the other Hopi varieties showed the same tendency in all experiments.

Detailed observations of the feeding habits of pink bollworm larvae indicated that larvae began feeding on lint and the outer seed coat after entry into green cotton bolls with immature seed. The cottonseed were not entered until the seed became firm inside. After larvae began feeding on the seed, they completed development on one or two adjacent seed. However, larvae feeding outside the seed moved about in the bolls considerably, resulting in frequent contact with other larvae and increased larval mortality inside the cotton boll.

The Hopi cottons matured earlier than the other cottons in these experiments. Therefore, seed of Hopi were suitable for larval entry before those of Deltapine 15 and the other cottons. Bolls of all cottons were infested with pink bollworms at approximately the same age. Therefore, larval mortality was lower inside the more mature Hopi bolls than in Deltapine 15 bolls because the larvae were able to enter mature seed earlier and feed in a relatively protected spot.

Oviposition Experiments

Results of the 1954 field plot experiments, as presented in the preceding section, indicate that highly significant numbers of *G. thurberi* bolls were escaping pink bollworm damage. The escape of bolls from pink bollworm damage was observed early enough in the 1954 season to permit preliminary tests to determine why. The most likely explanation seemed to be that the bolls escaped injury because the moths did not oviposit as readily on *G. thurberi* bolls as on bolls of other cottons present in the cages.

In test 1, adjacent rows of Deltapine 15 and *G. thurberi* were caged together. The mean number of eggs found per boll for Deltapine 15, Table 5, was 19.6 and 1.2 for *G. thurberi.* Percentages of bolls that escaped oviposition were 5.3 and 79.1 for Deltapine 15 and *G. thurberi,* respectively. These results indicated that Deltapine 15 bolls were preferred for oviposition to *G. thurberi* and resulted in significant numbers of the bolls of *G. thurberi* escaping injury.

The location of the pink bollworm eggs found on the *G. thurberi* bolls was different from their location on bolls of Deltapine 15. The distribution of the eggs on Deltapine 15 was 56.4 percent under the calyx, 42.4 percent on the boll inside the bracts and 1.2 percent below the bracts around the nectaries. All the eggs found on *G. thurberi* bolls were around the base of the boll in a tight groove formed by the calyx and bracts. This groove was found only on bolls 3 weeks or more old, in which the enlarged circumference of the boll forced the calyx basally and caused it to bulge outward at the point of attachment. Thus, eggs were found only on the older *G. thurberi* bolls. The significant point illustrated by this test was that no eggs were found under the calyx of the bolls of *G. thurberi,* the location that generally was considered to be preferred by the moth for oviposition.

Test 2 conducted during 1954 was designed to force the insect to oviposit on *G. thurberi.* This test was conducted simultaneously with test 1 and in the same manner except that only *G. thurberi* plants were present in the cage. The results are shown in Table 5. Eight eggs were found under the calyx of two bolls. The calyx of both bolls had split and was abnormal. The remainder of the eggs were found in the same location on the *G. thurberi* bolls as described for test 1. When the moths were forced to oviposit on *G. thurberi,* the average number of eggs found per boll increased to 4.2, and the bolls that escaped with no eggs decreased to 52.9 percent. It was significant that such a large number of the bolls

TABLE 5. LOCATION OF EGGS DEPOSITED ON BOLLS BY PINK BOLLWORM ADULTS ON SPECIES OF COTTON AS INDICATED AT COLLEGE STATION, 1954

Cotton	Under calyx		On boll[1]		Below bract[2]		Total eggs	Total bolls	Eggs per boll	Bolls escaped	
	No. eggs	Percent	No. eggs	Percent	No. eggs	Percent				No. bolls	Percent
					Test 1						
Deltapine 15	419	56.4	315	42.4	9	1.2	743	38	19.6	2	5.3
G. thurberi	0	0	137	100.0	0	0	137	110	1.2	87	79.1
					Test 2						
G. thurberi	8	2.3	347	97.7	0	0	355	85	4.2	45	52.9

[1]Eggs found inside the bracts but not under the calyx.

[2]Eggs found below the bracts around the nectaries.

escaped selection for oviposition when the cotton was exposed to a high level of pink bollworm infestation without other cotton.

Apparently, these results indicated that either the pink bollworm moths were repelled by chemotropic factors, or the morphological characteristics of this cotton did not afford suitable sites for the moths to oviposit. The results of test 1 tend to eliminate the theory of chemotropic factors causing the moths to prefer Deltapine 15 bolls. With Deltapine 15 bolls available for oviposition in the cage, 20.9 percent of the *G. thurberi* bolls had pink bollworm eggs deposited on them. It seemed reasonable that, under the conditions of this test, if the moths were repelled by some chemical constituent of *G. thurberi* bolls, more of the eggs would have been laid on the Deltapine 15 bolls.

The difference in morphological characteristics of *G. thurberi* bolls apparently was the cause for the nonpreference of the moths for oviposition on this cotton. Therefore, tests were conducted in 1955 to determine the effects of various morphological differences in vegetative and fruiting parts of several cottons on the location and numbers of eggs deposited by pink bollworm moths. The results of seven tests are given in Tables 6, 7 and 8.

Pink bollworm moths deposited more eggs under the calyxes and fewer on the bolls of *G. herbaceum*. This reduction of the percentage of eggs laid on the bolls apparently was caused by the bracts of *G. herbaceum* flaring away from the boll, leaving the smooth boll completely exposed. It has been observed that pink bollworm moths do not oviposit on smooth, open surfaces. Apparently the egg-laying reaction must be "triggered" by the stimulus resulting from placing the abdomen and ovipositor into a crevice or close-fitting place. Thus, the only suitable location for oviposition on *G. herbaceum* bolls was under the calyx. These results indicated that a difference in the structural parts of the cotton boll caused a difference in the preferred location for egg-laying of pink bollworm moths.

The vegetative characters of Texas 536 apparently were unattractive to the pink bollworm moth for oviposition since no eggs were found on the vegetative parts. Thus, all the eggs on this plant were laid on the bolls. The distribution of eggs on the bolls was in the same proportion as for Deltapine 15 but more eggs were found per boll on Texas 536 than for Deltapine 15. The narrow bracts did not seem to affect the preference of the pink bollworm moth for oviposition.

Apparently, the structural characters of the vegetative parts of Pima provided a better location for pink bollworm oviposition than did the fruiting parts. In all tests that included Pima, except one, the percentage of eggs laid on the vegetative parts was higher than that laid

TABLE 6. NUMBER AND PERCENTAGE OF PINK BOLLWORM EGGS DEPOSITED ON VEGETATIVE PARTS OF SEVERAL COTTONS AS INDICATED AT COLLEGE STATION, 1955

Cotton	No. plants	Leaves		Terminals		Axils		Total eggs
		No. eggs	Percent	No. eggs	Percent	No. eggs	Percent	
				Test 1				
Deltapine 15	10	109	24.8	110	25.0	221	50.2	440
G. herbaceum	10	54	21.9	67	27.1	126	50.0	247
Frego bract	4	33	24.4	21	15.6	81	60.0	135
				Test 2				
Deltapine 15	5	44	17.0	107	41.5	107	41.5	258
Pima	5	54	24.5	3	1.4	163	74.1	220
				Test 3				
Deltapine 15	6	49	17.4	22	7.8	211	74.8	282
Pima	6	238	49.8	5	1.0	235	49.2	478
				Test 4				
Deltapine 15	3	8	22.9	4	11.4	23	65.7	35
Texas 536	6	0	0	0	0	0	0	0
Pima	10	184	46.6	0	0	211	53.4	395
				Test 5				
Deltapine 15	6	108	29.0	37	10.0	227	61.0	372
Pima	6	1,081	72.9	9	0.6	392	26.5	1,482
G. thurberi	6	33	17.6	0	0	155	82.4	188
				Test 6				
Deltapine 15	5	80	24.5	56	17.1	191	58.4	327
Pima	5	100	38.3	0	0	161	61.7	261
G. thurberi	6	5	12.2	0	0	36	87.8	41
				Test 7				
Deltapine 15	5	33	12.9	5	1.9	219	85.2	257
Pima	5	339	83.1	3	0.7	66	16.2	408
G. thurberi	10	4	7.1	0	0	52	92.9	56

on the fruiting parts. The larger number of eggs found on the leaves of Pima indicated that they were preferred to the axils or terminals for oviposition. Also, more eggs were found on the leaves of Pima than on the leaves of Deltapine 15. This apparently was caused by the coarser pubescence and the larger leaf veins of Pima. The percentage of eggs found under the calyx of Pima bolls not over 3 weeks old was smaller than the percentage found on older bolls. After the bolls became 4 weeks or older, more eggs were found under the calyx than on the boll. This was caused by the split and distorted calyx of older Pima bolls. The calyx would split when the circumference of the growing boll became too large for it. The moths would oviposit under the calyx at the splits. Relatively few eggs were found under the undamaged calyx of younger bolls. Apparently, the calyx was fitted too tightly for the pink bollworm moth to insert the ovipositor under it.

Results of the tests in which *G. thurberi* was included indicated that the morphological characters of this cotton exerted a marked influence on the number and location of eggs laid by the pink bollworm moth. Significant numbers of the bolls of this cotton in all tests escaped oviposition and injury by the pink bollworm. The numbers of eggs found in all oviposition sites on *G. thurberi* were significantly lower than for the other cottons tested. The ratio of eggs found on vegetative to fruiting parts was about 50-50. All eggs found under the calyx were located at broken or distorted points of the calyx. Eggs were not found on the bolls until the latter were approximately 3 weeks or more old. In many cases when the *G. thurberi* boll became fully grown, the circumference of the boll became too large for the calyx. Rarely did the calyx split, but it usually was pushed downward toward the base of the boll and remained tight and smooth against the carpel at the outer edge. The result was the formation of a narrow, tight groove between the outside of the calyx and inner side of the bracts at the base of the boll. This was the point at which all eggs were found on normal bolls of this cotton. These results indicated that no favorable site for pink bollworm oviposition existed on *G. thurberi* bolls until they were 3 weeks or more of age. Another outstanding feature of these experiments was the very small number of eggs found per boll and per plant of *G. thurberi* compared with the other cottons. Thus, the vegetative parts also afforded poor sites for pink bollworm oviposition.

The results of test 7, Tables 6, 7 and 8, indicated that the vegetative parts of Pima and Deltapine 15 were preferred for oviposition to *G. thurberi* with fruit present. The oviposition sites

TABLE 7. NUMBER AND PERCENTAGE OF PINK BOLLWORM EGGS DEPOSITED ON FRUITING PARTS OF SEVERAL COTTONS AS INDICATED AT COLLEGE STATION, 1955

Cotton	No. plants	Squares		Under calyx		On boll[1]		Below bract[2]		Total eggs
		No. eggs	Percent	No. eggs	Percent	No. eggs	Percent	No. eggs	Percent	
				Test 1						
Deltapine 15	10	0	0	810	61.9	425	32.5	74	5.6	1,309
G. herbaceum	10	0	0	1,118	96.1	37	3.2	8	0.7	1,163
Frego bract	4	0	0	304	71.7	112	26.4	8	1.9	424
				Test 2						
Deltapine 15	5	0	0	160	30.9	326	63.1	31	6.0	517
Pima	5	0	0	83	53.9	71	46.1	0	0	154
				Test 3						
Deltapine 15	6	0	0	397	35.2	677	60.0	54	4.8	1,128
Pima	6	0	0	128	43.7	165	56.3	0	0	293
				Test 4						
Deltapine 15	3	0	0	81	82.7	17	17.3	0	0	98
Texas 536	6	0	0	195	82.3	42	17.7	0	0	237
Pima	10	0	0	129	56.8	98	43.2	0	0	227
				Test 5						
Deltapine 15	6	0	0	722	44.7	862	53.3	32	2.0	1,616
Pima	6	0	0	694	47.9	742	51.3	12	0.8	1,448
G. thurberi	6	0	0	2	2.8	70	97.2	0	0	72
				Test 6						
Deltapine 15	5	0	0	450	48.7	427	46.3	46	5.0	923
Pima	5	0	0	436	77.0	130	23.0	0	0	566
G. thurberi	6	0	0	13	16.0	68	84.0	0	0	81
				Test 7						
Deltapine 15	5			No fruit[3]						
Pima	5			No fruit[3]						
G. thurberi	10	0	0	0	0	12	100.0	0	0	128

[1]Eggs found inside the bracts but not under the calyx.
[2]Eggs found below the bracts around the nectaries.
[3]Fruit removed from Deltapine 15 and Pima.

found on the vegetative parts of these two cottons were more suitable for stimulating the egg-laying reaction of the pink bollworm moth than were the sites on fruits and vegetative parts of *G. thurberi.*

The results of the oviposition tests indicated that morphological differences of the cotton plant caused modifications of the oviposition habits of the pink bollworm moth. Fruit characteristics of tight, straight calyx and flared or deciduous bracts apparently made the fruiting parts unattractive for oviposition. Characters of heavy, prominent ribs of the leaf blade and pubescence on the entire vegetative parts of the plant made the vegetative parts more attractive for oviposition. If these characters could be obtained in one cotton, then a shift of the preferred place of oviposition from the protected sites on the fruit to the open vegetative parts might be expected. Such a shift would enable predators and parasites to become more effective as natural control measures. In addition, the larvae would be forced to migrate in search of fruit to survive and greater mortality would result. The exposure of the larvae to chemicals would be greater during migration in search of food and should give more efficient chemical control.

The literature revealed that most of the major cotton pests that oviposited on an open, unprotected portion of the cotton plant had extremely high reproductive potentials. According to Little and Martin (1942) the cotton leafworm, *Alabama argillacea* (Hbn.), laid an average of 500 eggs. The bollworm, *Heliothis zea* (Boddie), was recorded as laying over 3,000 eggs. The tobacco budworm, *Heliothis virescens* (F.), may lay over 1,000 eggs. Of the insects that lay eggs in a protected site, the pink bollworm may lay 100 to 200 eggs. The boll weevil, *Anthonomus grandis* Boh., lays about 100 eggs. The cotton fleahopper, *Psallus seriatus* (Reut.), lays approximately 30 eggs. These data indicated that an insect which oviposits in an open, unprotected site needs a higher reproductive potential to insure survival. Thus, any change in the host plant that would result in a preference of exposed sites for oviposition by the pink bollworm, which has a relatively low reproductive potential, could be detrimental to the survival of this pest.

TABLE 8. PINK BOLLWORM EGGS DEPOSITED ON VEGETATIVE AND FRUITING PARTS OF COTTON PLANTS WITH VARIOUS MORPHOLOGICAL DIFFERENCES AT COLLEGE STATION, 1955

Cotton	No. Plants	Vegetative parts		Fruiting parts		Total bolls counted	Eggs per boll	Total eggs
		No. eggs	Percent	No. eggs	Percent			
				Test 1				
Deltapine 15	10	440	25.2	1,309	74.8	103	17.0	1,749
G. herbaceum	10	247	17.5	1,163	82.5	106	13.2	1,410
Frego bract	4	135	24.2	424	75.8	21	20.2	559
				Test 2				
Deltapine 15	5	258	33.3	517	66.7	40	19.4	775
Pima	5	220	58.8	154	41.2	47	8.0	374
				Test 3				
Deltapine 15	6	282	20.0	1,128	80.0	57	19.8	1,410
Pima	6	478	62.0	293	38.0	55	5.3	771
				Test 4				
Deltapine 15	3	35	26.3	98	73.7	20	4.9	133
Texas 536	6	0	0	237	100.0	33	7.2	237
Pima	10	395	63.5	227	36.5	118	1.9	622
				Test 5				
Deltapine 15	6	372	18.7	1,616	81.3	43	37.6	1,988
Pima	6	1,482	50.6	1,448	49.4	42	34.5	2,930
G. thurberi	6	188	72.3	72	27.7	102	0.7	260
				Test 6				
Deltapine 15	5	327	26.2	923	73.8	45	20.5	1,250
Pima	5	261	31.6	566	68.4	34	16.6	827
G. thurberi	6	41	33.6	81	66.4	236	0.4	127
				Test 7				
Deltapine 15	5	257	100.0	No fruit[1]				257
Pima	5	408	100.0	No fruit[1]				408
G. thurberi	10	56	30.5	128	69.5	159	0.8	184

[1]Fruit removed from Deltapine 15 and Pima.

BIBLIOGRAPHY

Adolph, Edward F. 1920. Egg-laying reactions of the pomace fly, *Drosophila.* Jour. Expt. Zool. 31: 327-341.

Anson, R. R., R. L. Knight, and S. H. Evelyn. 1945. Progress report of the plant breeding stations, bollworm resistance. Empire Cotton Growing Corp. Rpt. Expt. Stas. 1943-44: 67-68.

Audant, A., and A. Occenad. 1937. The Mexican cotton boll weevil *Anthonomus grandis* Boheman, in Haiti. Univ. Puerto Rico Jour. Agri. 21: 69-76.

Ballou, H. A. 1918. The pink bollworm in Egypt. Jour. Econ. Ent. 11: 236-245.

Brazzel, J. R., and D. F. Martin. 1955. Behavior of pink bollworm larvae. Jour. Econ. Ent. 48: 677-679.

Busck, August. 1917. The pink bollworm, *Pectinophora gossypiella,* Jour. Agri. Res. 9: 343-370.

Chapman, A. J. 1937. Varietal resistance (to pink bollworm). Texas Agr. Expt. Sta. Ann. Rpt. 50: 62-63.

.....1938. Pink bollworm. Texas Agr. Expt. Sta. Ann. Rpt. 51: 44.

Chapman, A. J., *et al.* 1941. Cotton varieties. Texas Agr. Expt. Sta. Ann. Rpt. 54: 35.

Cunliffe, N., and D. J. Hodges. 1946. Studies on *Oscinella frit* L. Ann. Appl. Biol. 33: 339-360.

Currie, G. A. 1932. Oviposition stimuli of the burr seed fly, *Euaresta aequalis* Loew. Bul Ent. Res. 23: 191-193.

Dahms, R. G. 1943. Insect resistance in sorghum and cotton. Amer. Soc. Agron. Jour. 35: 704-715.

Dark, S. O. S., and J. H. Saunders. 1955. Progress report of the Shambat Experiment Station. Empire Cotton Growing Corp. Rpt. Expt. Stas. 1954-55: 15-16.

Davidson, W. M., and R. L. Nougaret. 1921. The grape phylloxera in California. USDA Ent. Bul. 903. 128p.

Durrant, J. H 1912 Notes on Tineina bred from cotton bolls. Bul. Ent. Res. 3: 203-208.

Fenton, F. A. 1928. Biological notes on the pink bollworm (*Pectinophora gossypiella* Saunders) in Texas. Fourth Internatl. Cong. Ent. 2: 439-447.

Fenton, F. A., and W. L. Owen. 1953. The pink bollworm of cotton in Texas. Texas Agr. Expt. Sta. Misc. Pub. 100. 39 p.

Folsom, J. W. 1922. Entomology with special reference to its ecological aspects. P. Blakiston's Son and Co., Philadelphia. 3rd ed. 502 p.

Harland, C. S. 1929. A suggested method for the control of certain bollworms in cotton. Empire Cotton Growing Rev. 6: 333-334.

Heinrich, Carl. 1928. Some Lepidoptera likely to be confused with pink bollworm. Jour. Agr. Res. 20: 807-836.

Hilson, G. R. 1925. The improvement of the cotton crop. Empire Cotton Growing Rev. 2: 201-208.

Hinds, W. E. 1906. Proliferation as a factor in the natural control of the Mexican cotton boll weevil. USDA Bur. Ent. Bul. 59. 45 p.

Hunter, W. D. 1926. The pink bollworm, with special reference to steps taken by the Department of Agriculture to prevent its establishment in the United States. USDA., Dept. Bul. 1397. 30 p.

Husian, M. A., and M. H. Kahn. 1940. Studies on *Platyedra gossypiella* Saunders in the Punjab. IV. Relative incidence on exotic and indigenous varieties of cotton. Indian Jour. Ent. 2: 45-57.

Hutchinson, J. B., R. A. Silow, and S. G. Stephens. 1947. The evolution of *Gossypium* and the differentiation of the cultivated cottons. New York, Oxford Univ. Press. 160 p.

Jones, H. A., S. F. Bailey, and S. L. Emsweller. 1934. Thrips resistance in the onion. Hilgardia 8: 215-232.

Knight, R. L. 1944. Progress report of the Shambat Substation, Anglo-Egyptian Sudan. Empire Cotton Growing Corp. Rpt. Expt. Stas. 1942-43: 73.

————. 1946. Progress report of the Shambat Experiment Station. Empire Cotton Growing Corp, Rpt. Expt. Stas. 1944-45: 55-56.

———— 1947. Progress report of the Shambat Experiment Station. Empire Cotton Growing Corp. Rpt. Expt. Stas. 1945-46: 64.

———— 1948. Progress report of the Shambat Experiment Station. Empire Cotton Growing Corp. Rpt. Stas. 1946-47: 63-64.

———— 1949. Progress report of the Shambat Experiment Station. Empire Cotton Growing Corp. Rpt. Expt. Stas. 1947-48: 59.

Knight, R. L., S. O. S. Dark, and R. L. Cuany. 1953 Progress report of the Shambat Experiment Station. Empire Cotton Growing Corp. Rpt. Expt. Stas. 1952-53: 15.

Knight, R. L., S. O. S. Dark, and J. H. Saunders. 1954. Progress report of the Shambat Experiment Station. Empire Cotton Growing Corp. Rpt. Expt. Stas. 1953-54: 15-16.

Little, V. A., and D. F. Martin. 1942. Cotton insects of the United States. Burgess Publishing Co., Minneapolis, Minn. 130 p.

Loftin, U. C., K. B. McKinney, and W. K. Hanson. 1921. Report on investigations of the pink bollworm of cotton in Mexico. USDA., Dept. Bul. 918. 64 p.

MacDonald, D., W. L. Fielding, and D. F. Ruston. 1940. Barberton: Hybridization progress report. Empire Cotton Growing Corp. Rpt. Expt. Stas. 1938-39: 15-25.

Marlatt, C. L. 1918. The origin of the pink bollworm. Science n. s. 48: 309-312.

McColloch, J. W. 1920. A study of the oviposition of the corn earworm with relation to certain phases of life economy and measures of control. Jour. Econ. Ent. 13: 242-245.

Mumford, E. P. 1931. Studies in certain factors affecting the resistance of plants to insect pests. Science 73: 49-50.

Ohlendorf, W. 1926. Studies of the pink bollworm in Mexico. USDA., Dept. Bul. 1374. 64 p.

Painter, R. H. 1943. Insect resistance of plants in relation to insect physiology and habits. Amer. Soc. Agron. Jour. 35: 725-732.

Painter, R. H. 1951. Insect resistance in crop plants. The Macmillan Co., New York. 520 p.

Parnell, F. R. 1935. Origin and development of U.4 cotton. Empire Cotton Growers Rev. 12: 177-182.

Parnell, F. R., H. E. King, and D. F. Ruston. 1949. Jassid resistance and hairyness of the cotton plant. Bul. Ent. Res. 39: 539-575.

Peterson, C. E., and E. S. Habner. 1942. The relation of leaf structure to thrips resistance in the onion. Amer. Hort. Sci. Proc. 40: 421-422.

Poos, F. W., and F. F. Smith. 1931. A comparison of oviposition and nymphal development of *Empoasca fabae* (Harris) on different host plants. Jour. Econ. Ent. 24: 361-371.

Richardson, C. H. 1925. The oviposition response of insects. USDA., Dept. Bul. 1324. 17 p.

Saunders, W. W. 1843. Description of a species of moth destructive to the cotton crops in India. Trans. Ent. Soc. London. 3: 284-285.

Snelling, R. O. 1941. Resistance of plants to insect attack. Bot. Rev. 7: 543-586.

Squire, F. A. 1939. A note on the resistance of *Hibiscus esculentus* and *Gossypium trilobum* to *Platyedra gossypiella* Saund. Empire Growing Rev. 16: 268-271.

Wolcott, G. R. 1927. Haitian cotton and the pink bollworm. Bul. Ent. Res. 18: 79-82.

———— 1928. The pink bollworm in Haiti. Fourth Internatl. Cong. Ent. Ithaca, Trans. 2: 68-72.