Studies of Pest and Beneficial Insects in Arizona Stub and Planted Cotton

U.S. Department of Agriculture
Agricultural Research Service
Agricultural Research Results•ARR-W-32/October 1983

A copy of this publication is available upon request from the Western Cotton Research Laboratory, 4135 East Broadway Road, Phoenix, Ariz. 85040.

International Standard Serial Number (ISSN) 0193-3817

Agricultural Research Service, Agricultural Research Results, Western Series, No. 32, October 1983

Published by Agricultural Research Service (Western Region), U.S. Department of Agriculture, Oakland, Calif. 94612

ABSTRACT

In each of 3 study years (*1978*, *1979*, *1980*), stub cotton, *Gossypium* spp., fruiting in commercial fields began approximately 4 to 6 weeks earlier than fruiting in planted cotton. The numbers of male pink bollworm, *Pectinophora gossypiella* (Saunders), moths caught early in the growing season in gossyplure-baited Delta traps were significantly higher in stub cotton than in planted cotton. Pink bollworm larval infestations in squares and bolls and *Heliothis* spp. oviposition occurred 4 to 6 weeks earlier in stub cotton than in planted cotton.

Under controlled experimental conditions, approximately 2.6 times more moths from overwintered pink bollworm larvae emerged in stub cotton than in planted cotton. About 62 percent of the moths emerging in stub cotton, compared with 10 percent of the moths emerging in planted cotton, had host material (squares) available for reproduction as a result of the earlier growth of the stub cotton. Boll infestations in the stub cotton were first found during the week ending June 21, and economic infestation levels of 15 percent or more were reached by the week ending July 26. In contrast, economic level boll infestations occurred in adjacent planted cotton during the week ending August 16 and in distant (265 m) planted cotton during the week ending August 30.

Infestations of boll weevil, *Anthonomus grandis* Boheman, were found in squares and/or bolls, or adults were caught in grandlure-baited traps in stub cottonfields on three ranches in western Maricopa County in 1978, the first year of the stub cotton study. The wet, cold winter of 1978 to 1979 limited stub cotton production during 1979, and no boll weevils were found during the 1979 growing season. When approximately 24,000 ha of stub cotton were grown in 1980 and 1981, boll weevils were found in squares, bolls, and/or caught in traps in stub cottonfields on 6 ranches in the Cosmos area and 1 ranch near Gila Bend during 1980, and on 1 ranch in Rainbow Valley, 2 ranches near Buckeye, 1 ranch in Harquahala Valley, 12 ranches in the Cosmos area, 3 ranches near Gila Bend, 3 ranches in the Hyder area, and 3 ranches near Aztec in 1981 in stub and planted cotton.

Lygus spp.; whitemarked fleahopper, *Spanagonicus albofasciatus* (Reuter); cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter); and cotton leafperforator, *Bucculatrix thurberiella* Busck, populations during the 3 years of the study were not of economic significance in either stub or planted cotton. Beneficial predaceous insects were high in both stub and planted cotton production systems early in the season and declined thereafter.

Insecticide applications were applied earlier to stub cotton than planted cotton but averaged only about one additional application to stub cotton vs. planted cotton and controlled pink bollworm and *Heliothis* spp. effectively in both cotton cultural systems.

KEYWORDS: Stub cotton, planted cotton, pink bollworm, boll weevil, traps, infestations, *Heliothis*, overwintering, gossyplure, grandlure, bolls, squares, beneficial predaceous insects, insecticide applications, commercial grower fields, emergence, flowering cycle, field cages, diapausing larvae, Arizona, southern California, populations, oviposition, plant terminal damage, plant bugs, cotton leafperforator, cultural control practices, cotton production systems.

CONTENTS

Page

STUDIES OF PEST AND BENEFICIAL INSECTS IN ARIZONA STUB AND PLANTED COTTON

By D. Bergman, T. J. Henneberry, L. A. Bariola, and J. M. Gillespie[1]

INTRODUCTION

The cotton, *Gossypium* spp., plant is perennial in growth habits; however, in most of the United States it is grown as an annual plant because (1) it fails to survive killing frosts and (2) it has more pest problems when grown as a perennial (Wene *1965*; Fye *1968*; Fye and Parencia *1972*; van Schaik et al. *1962*).[2] Evanson (*1970*) reviewed the reports of stub or ratoon cotton grown in many parts of the world. He concluded that in some circumstances, perennial cotton was advantageous and had been reported successfully grown in Peru, British Guiana, Brazil, Western United States, South Africa, Israel, and northwestern Australia. Yields were equal to or higher than those from annual planted cotton when one managed to avoid insect pests, diseases, and weeds, but he reported lint quality data were conflicting. Ratoon cotton was characterized as flowering earlier and requiring less fertilizer but having more serious weed problems than the annual crop. Disease and insect pest problems varied considerably. For example, in Egypt, early regrowth of ratoon cotton supported populations of spiny bollworm, *Earias insulana* (Bdv.), and annual cotton in close proximity to ratoon cotton suffered higher losses from bollworms than in the absence of ratoon cotton (Bishara *1930*). In South Africa, Rainey and Smith (*1950*) reported similar experiences with the red bollworm, *Diparopsis castanea* (Hmps.), and the cotton stainer, *Dysdercus fasciatus* (Sign.).

Stub cotton has been grown in Arizona except when prohibited under State and Federal quarantines because of the threat of spreading pink bollworm, *Pectinophora gossypiella* (Saunders), and boll weevil, *Anthonomus grandis* Boheman, infestations. Wene (*1965*) concluded that stub cotton was related to increased problems with pink bollworm, and Fye (*1968*) reported that damage from the boll weevil in Arizona was greater in stub cotton than in planted cotton.

---

[1]Bergman is a research technician, Department of Entomology, University of Arizona, Tucson; Henneberry and Bariola are entomologists, Western Cotton Research Laboratory, Western Region, Agricultural Research Service (ARS), U.S. Department of Agriculture (USDA), Phoenix, Ariz.; and Gillespie is Manager, Pheromone Programs, Hercon Division, Health-Chem Corp., Phoenix.

[2]The year in italic, when it follows the author's name, refers to Literature Cited, p. 14.

van Schaik et al. (*1962*) reported that the incidence of cotton leaf crumple disease, transmitted by the sweetpotato whitefly, *Bemisia tabaci* (Gennadius), in Arizona and southern California increased with the practice of stubbing cotton. Extensive grower interest in stub cotton culture because of potential yield increases, the availability of new chemicals for pest control, and increased energy and other production costs prompted the initiation in 1978 of a cooperative research study involving the University of Arizona, USDA-ARS, Arizona Commission of Agriculture and Horticulture, and participating cotton growers to evaluate pest, disease, agronomic, and economic aspects of stub cotton growing with currently available production technology (Beatty *1977*). Some of the results of the agronomic, weed, and disease studies have been reported elsewhere (Taylor and Hathorn *1979a*, *1979b*, *1979c*, *1981*) as well as progress reports of the entomological work (Gillespie et al. *1979*; Bergman et al. *1980*, *1981*). The present paper is a complete analysis of the entomological research results from 1978 to 1981.

PROCEDURES

General

In 1978, commercial stub and adjacent planted cottonfields of at least 32 ha were selected as experimental sites at each of 10 locations. Stub, adjacent planted, and distant planted cotton (0.8 to 1.6 km from stub fields) were selected at each of two and five locations in 1979 and 1980, respectively. In 1981, 5 stub and 10 planted fields (about 32 ha each) were selected for boll weevil studies. Numerous other fields were also inspected to detect and study the spread of infestations of the insect. In 1979, each of the three treatments was replicated twice at each of the two locations. Experimental stub and planted fields at all locations in 1979 and 1980 were about 17 to 28 ha each. Cottonfields in each year of the study were in Maricopa and Pinal Counties in Arizona (fig. 1).

Sampling in commercial fields for pink bollworm, *Heliothis* spp., cotton leafperforator, *Bucculatrix thurberiella* Busck, boll weevil, plant bugs, *Lygus* spp., cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter), whitemarked fleahopper, *Spanagonicus albofasciatus* (Reuter), and selected insect predators ((*Orius* spp., *Geocoris* spp., assassin bugs (Reduviidae), *Nabis* spp., green lacewings (*Chrysopa* spp.), and lady beetles (Coccinellidae)) was initiated the last week in April to May 7 in each year, except in the 1981 boll weevil studies, and continued through the last week in September.

Pink Bollworm and Boll Weevil

Five gossyplure-baited Delta traps (Sandia Die and Cartridge Co., Albuquerque, N. Mex.) were installed in each stub and planted cottonfield to study pink bollworm male moth activity in each type of cotton culture (Foster et al. *1977*). Traps were installed the first week in May and operated through the last week of September in each year. Pheromone baits, containing 1 mg gossyplure on rubber septa (Flint et al. *1976*), were replaced monthly. Traps were replaced when

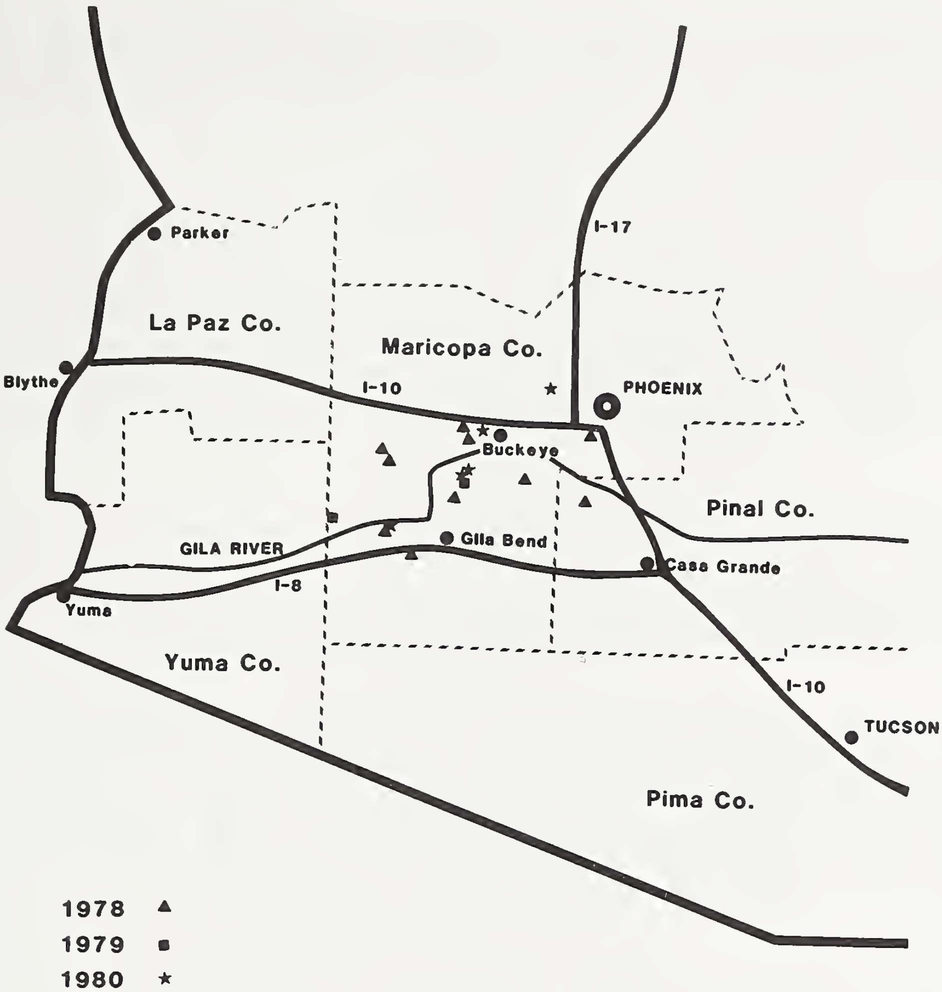


Figure 1.--Experimental stub and planted cottonfield locations in Arizona in 1978, 1979, and 1980.

catches exceeded 50 moths. In addition, in 1979 and 1980, to measure male moth activity outside cottonfields and in cotton fields prior to cotton fruiting, two sets of five pink bollworm pheromone traps were placed in the desert at least 0.4 km from the nearest cotton at each location April 24 to 26, and operated until June 30. Boll weevil traps (Legget and Cross *1971*), baited with 3 mg of grandlure, were installed in each field. Traps were checked weekly and baits changed every 2 weeks. Additionally, boll weevil traps were installed in other cottonfields when infestations were detected to record movement and spread of infestations.

Fifty to 100 mature squares were collected weekly in each field until the end of August and examined for pink bollworm and boll weevil feeding punctures, eggs and larvae, and darkened pollen sacs, indicating plant bug feeding. In 1979, numbers of flowers were counted on all plants in 1.1 m of row at each of five locations in each field and in 1980 on all plants in 30 m of row at two locations in each field to compare boll set curves of stub and planted cotton in relation to the availability of bolls as oviposition sites for pink bollworm moths. One hundred firm green bolls (about 14 to 21 days old) were collected in each stub field beginning in mid-June and in planted fields beginning in mid-July and continuing through September. Bolls from each sample were examined for exit holes and cut open to determine the presence of pink bollworm larvae and boll weevil larvae, pupae, and adults.

Pink bollworm overwintering and seasonal development in stub and planted cotton were also studied at Arizona State University Experimental Farm, Tempe, in 1980. The cotton stalks in 16 rows of a 5.6-ha cottonfield from seed planted in 1979 were cut (stubbed) to about 7.5 cm in height in March 1980. The remaining stalks were cut and shredded, and the field was plowed, disked, and cultivated. On April 14, 1980, 290 rows of cottonseed were planted adjacent to the stubbed cotton. The stub and planted cotton plots were irrigated as needed from April 7 until October 3, 1980.

The numbers of pink bollworm moths emerging from overwintered larvae in stub and planted cotton were determined by placing 24 screened pyramid (1 m^2) emergence cages (Shiller *1946*), over the soil in the stub and planted cotton plots from March 26 to April 23, 1980. Emerged pink bollworm adults in the cages were counted and sexed daily from March 27 to June 30.

Infestations developing from pink bollworm moths emerging in stub cotton and infestations augmented by moths moving into the stub cotton from outside sources were compared by placing four screened field cages (7.3 X 2.7 X 1.8 m) over stub cotton on April 1 and four screened field cages over stub cotton approximately 8 weeks later on June 5. Four screened and four unscreened field cages were placed over planted cotton on June 4.

The total numbers of flowers and pink bollworm infested flowers were counted daily, except on weekends, in all field cages from June 5 to October 20. Twenty-five firm green bolls (about 14 to 21 days old) were collected from the cotton plants in each field cage weekly and held for 21 days in ventilated plastic boxes, as described by Fye (*1976*). During the third week after collection, pink bollworms were counted and all bolls were opened and inspected for larvae.

The effect of pink bollworm populations developing in the stub cotton and infestations in the adjacent planted cotton, as well as planted cotton 265 m distant, was determined by collecting mature cotton squares and firm green bolls (100 each) from each of the areas twice weekly. The squares and 50 of the bolls were opened and examined for pink bollworm larvae. The remaining 50 bolls, were held in ventilated plastic boxes as previously described. Beginning in August, larvae collected from the plastic boxes were used to determine the percentages of larval diapause, as described by Bariola and Henneberry (*1980*).

Heliothis spp.

Beginning the first week of May each year, 100 plant terminals in each of the commercial stub cottonfields were examined for the presence of *Heliothis* spp. eggs, larvae, and terminal damage. Similar sampling in all planted fields began about the third week in May of each year. Damage was recorded if the terminal bud and/or pinhead or older squares showed evidence of *Heliothis* spp. larval feeding.

Other Insects

The numbers of adult and immature forms of pest and selected beneficial insects (*Orius*, *Geocoris*, *Nabis*, *Chrysopa*, Reduviidae, Coccinellidae, *Collops*, and spiders) were recorded weekly in standard samples of 100 sweeps of cotton rows beginning late April to early May in each stub field and during June in the planted fields. Sampling in each year was continued until mid-September.

Insecticides

Information concerning insecticides applied, rates, and dates of application on commercial grower fields was obtained from insecticide applicators and/or grower-employed pest control advisors.

Data tabulation for the 1978, 1979, and 1980 studies in commercial fields was facilitated by adjusting calendar dates to numbered weeks of the stub and planted cotton-growing season for each year, as shown in table 1. Data were tabulated as the means for each species for each sampling period for the 3 years of the study. All data were subjected to analyses of variance and Duncan's multiple range mean separation at the 19:1 probability level.

RESULTS

Pink Bollworm

For the first 8 weeks of gossyplure trapping, significantly more male pink bollworm moths were caught in grower stub cottonfields than in planted fields (fig. 2, average of 3 years' trapping data).[3] After July 1, the numbers of male moths caught in traps in stub and planted cotton were not significantly different.

The 1979 and 1980 data show that in early season (May through July), male moth trap captures in desert areas averaged about one male pink bollworm moth per trap/night (m/t/n) through the first 3 weeks in May and declined thereafter (fig. 3). No male moths were caught in the desert after mid-June. Through May and June, traps in the stub fields caught an average 1.5 m/t/n, ranging from 0.8 to 3.3. During the same period, captures in traps were less in the adjacent planted fields and averaged 0.6 m/t/n, ranging from 0.3 to 0.8, while captures

---

[3]Figures 2 to 18 follow the text, beginning on p. 17.

Table 1.--*Weekly stub and planted cotton sampling periods in 1979, 1980, and 1981 in Arizona*

Month	Week of sampling	Actual sampling dates 1978	1979	1980
May	1	4/30-5/6	4/29-5/5	4/27-5/3
	2	5/7 -5/13	5/6 -5/12	5/4 -5/10
	3	5/14-5/20	5/13-5/19	5/11-5/17
	4	5/21-5/27	5/20-5/26	5/18-5/24
	5	5/28-6/3	5/27-6/2	5/25-5/31
June	6	6/4 -6/10	6/3 -6/9	6/1 -6/7
	7	6/11-6/17	6/10-6/16	6/8 -6/14
	8	6/18-6/24	6/17-6/23	6/15-6/21
	9	6/25-7/1	6/24-6/30	6/22-6/28
July	10	7/2 -7/8	7/1 -7/7	6/29-7/5
	11	7/9 -7/15	7/8 -7/14	7/6 -7/12
	12	7/16-7/22	7/15-7/21	7/13-7/19
	13	7/23-7/29	7/22-7/28	7/20-7/26
August	14	7/30-8/5	7/29-8/4	7/27-8/2
	15	8/6 -8/12	8/5 -8/11	8/3 -8/9
	16	8/13-8/19	8/12-8/18	8/10-8/16
	17	8/20-8/26	8/19-8/25	8/17-8/23
	18	8/27-9/2	8/26-9/1	8/24-8/30
September	19	9/3 -9/9	9/2 -9/8	8/31-9/6
	20	9/10-9/16	9/9 -9/15	9/7 -9/13
	21	9/17-9/23	9/16-9/22	9/14-9/20
	22	9/24-9/30	9/23-9/29	9/21-9/27

in traps in the distant planted fields averaged 0.9 and peaked the first week in June at 1.7. Early in July, average male moth captures in the adjacent planted field increased abruptly and were greater than the average male moth captures in the distant planted fields. The monthly average for moths captured was greater in the stub fields than in either adjacent or distant planted fields in August, but greater in the adjacent planted fields than in either stub or distant planted fields in September (fig. 4). Male moth captures increased and were similar in all fields during October.

Square infestations in commercial fields (average of 3 years' data) were initiated in stub cotton by May 11 to 20 (fig. 5). An average of 1.1 percent (range 0 to 12 percent) of the squares sampled from stub fields in early May to early July were infested with pink bollworm larvae. No square infestations were found in planted cotton until the last week in June. Square infestations in stub and planted cotton were not different in mid-July through mid-August, but increased dramatically in stub cotton in late August and early September.

Flowering (boll set) in stub cotton began approximately 4 weeks earlier than in planted cotton (fig. 6). Peak flowering in stub cotton occurred the first week in July, decreasing thereafter to mid-August. In contrast, flowering in planted cotton began in late June, peaked in late July, and decreased to late August. From June 3 to 20, 1 to 3 percent of the sampled bolls in stub cotton were infested with pink bollworm larvae (fig. 7). Susceptible bolls were not available to pink bollworm in planted cotton until June 29 to July 8. During July and August, percentages of infested bolls were numerically higher in stub cotton than in planted cotton except for 1 week in late July, but the differences were not statistically different (fig. 7). Infestations in both stub and planted cotton bolls decreased to less than 1 percent in September as a result of insecticide applications.

The results of the 1980 pink bollworm overwintering studies in stub and planted cotton grown under controlled experimental conditions showed that from April 1 through June 23, 52 pink bollworm moths (21,700/ha) emerged in cages placed over stub cotton, and 20 moths (8,300/ha) emerged in cages over planted cotton with peak emergence occurring May 6 to May 26. However, approximately 62 percent (32) of the moths emerging in the stub cotton (first square May 15) and only 10 percent (2) of the moths emerging in the planted cotton (first square June 4) had host material (squares) available for pink bollworm reproduction (fig. 8, squares occurred about 3 weeks before flowers). Thus, about 90 percent of the moths emerged suicidally in the planted cotton compared with only 38 percent in the stub cotton (Bariola *1978*).

Flowers per field cage were greater in the stub cotton than in the planted cotton until mid-July (fig. 8). The first flowering cycle in the stub cotton peaked on June 20 with flowering decreasing thereafter until August 21 when the second flowering cycle began. The second flowering cycle in the stub cotton peaked on September 15 and declined thereafter. In contrast, the first flowering cycle did not begin until June 24 in the planted cotton, peaked July 28, and declined thereafter. The second flowering cycle in the planted cotton began increasing September 8 and peaked October 2.

The number of pink bollworm infested flowers per field cage from June 23 to July 3 was significantly greater in stub cotton caged June 5 than in stub cotton caged April 1 (fig. 9). The numbers of pink bollworm infested flowers per open field cage over planted cotton from July 17 to 28 were significantly greater than infested flowers in the screened field cages over planted cotton (fig. 10). Initial boll infestations (July 2) were significantly greater from stub cotton caged June 5 than boll infestations in stub cotton caged April 1 (table 2). From August 6 through September 17, pink bollworm larvae per 25 bolls from open cages over planted cotton were significantly greater than in bolls from cotton in the screened field cages.

In open field plots, stub cotton squares sampled during the week ending June 7 were infested (5.0 percent) with pink bollworm larvae (table 3). Planted cotton square infestations were not found until the week ending July 5. Square infestations in the stub cotton were higher than in either adjacent or distant planted cotton during 11 of 16 weeks throughout the sampling period. Square infestations were higher in the adjacent planted cotton than in the distant planted cotton throughout August and September.

Table 2.--*Mean*[1] *number of pink bollworms per 25 cotton bolls from plants in field cages placed over stub and planted cotton, Arizona State University Experimental Farm, Tempe, 1980*

Sampling date		Stub cotton caged		Planted cotton caged	
		April 1	June 5	June 4 (screened)	June 4 (open)
July	2	2 b	8 a	-	-
	9	4 a	4 a	-	-
	16	11 ab	21 a	0 c	3 bc
	23	7 b	30 a	0 b	8 b
	31	1 b	24 a	1 b	9 b
August	6	5 c	37 a	0 c	17 b
	14	50 b	103 a	3 c	42 b
	20	54 a	88 a	8 b	64 a
	27	67 b	106 ab	14 c	123 a
September	3	38 bc	57 b	20 c	111 a
	10	55 b	91 a	24 b	87 a
	17	58 b	59 b	25 c	91 a
	24	55 a	76 a	57 a	66 a

[1]Means of 4 replications. Means in the same row not followed by a common letter are significantly different according to Duncan's multiple range test, P=0.05.

Table 3.--*Percentages of pink bollworm infested cotton squares in stub, adjacent planted,*[1] *and distant planted*[2] *cotton, Arizona State University Experimental Farm, Tempe, 1980*

Week ending		Percent square infestations		
			Planted cotton	
		Stub cotton	Adjacent	Distant
June	7	5	-	-
	14	4	-	-
	21	3	0	0
	28	1	0	0
July	5	0	3	1
	12	0	1	1
	19	1	0	0
	26	0	0	3
August	2	2	2	1
	9	2	2	0
	16	4	2	1
	23	19	10	6
	30	20	10	5
September	6	12	7	5
	13	44	31	27
	20	25	35	31

[1]Planted cotton adjacent to the stub cotton.
[2]Planted cotton 265 m distant from the stub cotton.

Stub cotton boll infestations were first found the week ending June 21 (table 4). Economic infestation levels of 15 percent or more were found in the stub cotton by the week ending July 26 and in the adjacent planted cotton during the week ending August 16, but not in the distant planted cotton until the week ending August 30.

The first diapausing larva was found on August 29. The percentages of larvae in diapause were not different in stub and planted cotton, and the data are combined in figure 11. The percentage of larvae in diapause remained low through mid-September, then increased rapidly and reached 82 percent by October 7. This diapause response is similar to that reported by Bariola and Henneberry (*1980*) for Arizona and southern California.

Table 4.--*Mean*[1] *percentages of pink bollworm infested bolls in stub, adjacent,*[2] *and distant*[3] *planted cotton, Arizona State University Experimental Farm, Tempe, 1980*

Week ending		Percentages infested		
			Planted cotton	
		Stub cotton	Adjacent	Distant
June	21			
	28			
July	5	7	-	-
	12	10	-	-
	19	3	4	2
	26	17	0	1
August	2	13	2	9
	9	15	4	5
	16	24	36	6
	23	43	33	10
	30	58	42	19
September	6	61	56	46
	13	76	65	85
	20	65	70	69
	27	80	70	64
October	4	-	-	-
	11	-	-	-
	18	-	-	-
	25	-	-	-
November	1			-

[1] 50 bolls per twice weekly sample.
[2] Planted cotton adjacent to stub cotton.
[3] Planted cotton 265 m from the stub cotton.

Boll Weevil

The first boll weevil infestation was found on August 31, 1978, in a commercial stub cottonfield on a ranch (G1, fig. 12*A*) near Gila Bend. Approximately 11 percent of 811 squares examined were damaged by feeding and/or oviposition punctures. Square and boll infestations ranged from 2 to 22 percent from September to November 1978. Infestations occurred in another stub cottonfield on this ranch in 1978, but none were found in planted cottonfields in the area. Boll weevil traps caught about 27 adults per trap from September to December 1978. These insects and one boll weevil adult caught during October 1978 in a trap operated beside a stub cottonfield on a ranch (R1, fig. 12*A*) in Rainbow Valley were identified[4] as *Anthonomus grandis* Boheman, Mexican boll weevil form.

Boll weevils were found on an adjacent ranch at the same location (G2, fig. 12*A*) in early February 1979. Developmental cells (107) were found in 33 percent of the dry bolls collected from cotton stalks that remained in the stub cottonfield from the 1978 season. The cotton stalks on both ranches remaining from the 1978 season were shredded and the fields plowed during March 1979. Boll weevil traps (5 to 14) caught about 28 adults per trap on ranch G1 and about 16 adults per trap on ranch G2 from January through April 1979. Traps were operated through June 1979, but no additional boll weevils were caught. No boll weevil infestations were found in 1979 planted or stub cottonfields sampled during the growing season since only about 600 ha of stub cotton were grown in Arizona in 1979 (no stub cotton was grown in 1979 on or near the ranches with 1978 boll weevil infestations) because high mortality of 1978 stalks occurred during the wet, cold 1978-79 winter months. However, evidence of boll weevil infestations in 1979 cottonfields was found in another area in early February 1980 when developmental cells, averaging about 3750 per ha, were found in dry bolls remaining in 1979 stub cottonfields on two ranches (fig. 12*B*, C2, C3) at the Cosmos location.

Boll weevil infestations occurred on these two and four additional ranches (fig. 12*B*, C1, C4, C5, and C10). During the 1980 growing season, when about 24,000 ha of stub cotton were grown, boll weevil square infestations were about 2, 12, and 32 percent on May 6, June 10, and June 30, respectively, and peak boll infestations occurred June 16 to 23 in stub cottonfields on ranch C2 in the Cosmos area during 1980. Infestations ranging from about 1 to 3 percent were found in bolls collected from November to December 1980 in adjacent stub cottonfields on ranches C1, C3, C4, and C5. Infestations were not found in planted cottonfields in the area. Two adults were caught in traps operated on ranch C10 during September. Adult boll weevils were found feeding in blooms, and larval infestations occurred in both squares and bolls during September 1980 in a stub cottonfield on the same ranch (fig. 12*B*, G1) near Gila Bend where infestations occurred in 1978. A mild winter also preceded the 1981 cotton growing season,

---

[4] Horace Burke, Texas A&M University, College Station, Tex.

and about 24,000 ha of stub cotton were grown commercially. Adult boll weevils were trapped and/or infestations were found in squares or bolls on 25 ranches (fig. 12*C*), extending westward to Aztec and northwest to Harquahala Valley.

Heliothis Spp.

Oviposition, larval development, and damaged terminals caused by these insects were observed in commercial stub cottonfields the first week in May (figs. 13, 14, and 15), whereas, infestations were not found in planted fields until mid- to late June. Weekly averages for eggs per 100 terminals in both stub and planted cultures increased similarly through July and August, but significantly higher populations occurred in planted fields in September. Higher numbers of larvae were found in planted cotton in July. Plant terminal damage followed trends similar to egg and larval populations.

Other Insects--Plant Bugs and Cotton Leafperforator

Lygus spp., white marked fleahopper populations, and cotton leafperforator numbers were low and of little consequence in either stub or planted cotton during the study (figs. 16 and 17).

Beneficial Insects

High numbers of beneficial insects (*Orius* spp., *Geocoris* spp., Coccinellidae, *Chrysopa* spp., Reduviidae, *Nabis* spp., *Collops* spp., and spiders) were found early in the season in both planted and stub cultures (fig. 18). Populations were high through early July and declined thereafter. These results may have occurred because of insecticide applications and/or lack of prey since insect populations were generally low.

Insecticide Applications

The average number of foliar insecticide applications in stub and planted cotton commercial experimental plots (1978-80) was 11.1 and 10.3, respectively (table 5). Earliest applications to stub cotton occurred in February and to planted cottonfields in June. Insecticides effectively controlled pink bollworm and *Heliothis* spp. in both stub and planted cottonfields as indicated by the relatively low infestation levels in both stub and planted cotton grown under commercial conditions.

DISCUSSION

Early stub cotton regrowth resulted in fruiting forms available by mid-April to early May, depending on temperature, as oviposition sites and as a

Table 5.--*Mean*[1] *number of insecticide applications per month in experimental stub and planted cottonfields in Arizona in 1978, 1979, and 1980*

Month	Cotton cultural type	
	Stub	Planted
January	0	0
Feburary	.1	0
March	0	0
April	.1	0
May	.1	0
June	1.1	.3
July	2.7	2.0
August	4.4	4.7
September	2.2	2.6
October	.3	.7
Total	11.0	10.3

[1]Means of 19 fields each of stub and planted cotton for years 1978, 1979, and 1980.

source of larval food for initiation of pink bollworm infestations. Pink bollworm infestations were not initiated in planted cotton until mid-May to early June (Slosser and Watson *1972*).

Under commercial growing conditions, insecticide applications were initiated an average of 5 weeks earlier in stub cotton than in planted cotton because of earlier insect infestations, but were applied to planted fields 2 weeks longer. Insecticide applications for pink bollworm and *Heliothis* species control probably account for the low populations of cotton leafperforator, *Lygus* spp., whitemarked fleahopper, and cotton fleahopper. Insect infestations in stub or planted cotton were low in commercial study fields as a result of insecticide treatments and did not contribute to reduced yield (Taylor and Hathorn *1979a*, *1979b*).

In controlled experimental plots where no insecticides were applied during the growing season, more pink bollworm moths emerged the following spring from stub cotton than from planted cotton. These results agree with those of Watson et al. (*1974*), which demonstrated that cotton stalk destruction and plowdown significantly reduced overwintering pink bollworm populations. The earlier availability of host material (squares) resulted in potential reproduction for over 60 percent of the emerged moths in the stub cotton as compared with 10 percent of the emerged moths in the planted cotton where host material was not available until later in the season. Moths emerging in the surrounding area were attracted to the earlier fruiting stub cotton since higher infestations were found in stub cotton that had been exposed longest during the spring moth emergence period compared with stub cotton which had been protected by caging to exclude moths from outside sources. The development of an earlier pink bollworm generation in stub cotton squares also resulted in economic infestation levels in the stub cotton bolls occurring earlier in the season.

Pink bollworm moths of the first generation developed on stub cotton moved to the planted cotton when flowering decreased in the stub cotton. This was demonstrated by the significantly greater number of infested flowers which occurred in the open field cages over planted cotton compared with the number of infested flowers in the screened planted cottonfield cages.

Economic level boll infestations in the planted cottonfield plots adjacent to the stub cottonfield plots occurred 2 weeks earlier than in the planted cotton 265 m distant from the stub cotton.

Measurable infestations of the boll weevil had not been recorded in Arizona cotton since 1966 when stub cotton growing was banned and mandatory plowdowns and planting dates were enforced to maintain a host-free period. Boll weevils were found in stub cottonfields on three ranches during 1978 (the first year of the stub cotton research program) and the spring of 1979, but none were found during the 1979 growing season when stub cotton acreage was limited to about 600 ha. Boll weevils were found on seven ranches during 1980 and 25 ranches during 1981 in stub and planted cottonfields when about 24,000 ha of stub cotton were grown each year.

Stub cotton fruiting in April and May and early development of the plant canopy in stub fields probably provide suitable habitats for the development of early generations of weevils. In 1980 and 1981, increasing numbers of boll weevils were caught in grandlure-baited traps, indicating higher population levels. Fye et al. (*1969*) suggested that the threat of major boll weevil infestations was minimal until late season due to the high temperatures during a normal Arizona midsummer. They reported that temperatures above the range 30° to 35°C prolonged the development of the boll weevils. Also, frequent and prolonged exposure to soil temperatures greater than 38°C induced high levels of larval mortality in infested cotton squares that fall to the soil during May and June (Fye and Bonham *1970*). Early foliage shading in stub cotton cultural systems reduced soil temperatures below the canopy and thus increased the development time and reduced larval mortality of boll weevils in infested cotton squares.

The results of the present study support the conclusions of Fye et al. (*1970*) and Fye and Parencia (*1972*) that the early destruction of cotton stalks and subsequent burial of all debris are essential cultural control practices to prevent the development of high boll weevil populations in Arizona, as well as other late-season insect populations, such as the pink bollworm and bollworm complex.

Taylor and Hathorn (*1981*) reported that the costs of producing stub and planted cotton were similar, but higher yields were obtained from stub cotton culture. Flint et al. (*1980*) also reported that in an unreplicated field trial in Arizona, economical stub cotton production occurred without increased insecticide costs. The short-term advantage of higher yields must be carefully considered in relation to the disadvantage of developing an additional generation of pink bollworm and the possible establishment of the boll weevil as a permanent pest in Arizona cotton production systems.

ACKNOWLEDGMENT

The authors are grateful to Brian Beard and Jay Schied for their assistance in collecting and tabulating data and to the cotton growers and pest control advisors for their support and cooperation during these studies.

LITERATURE CITED

Bariola, L. A.
1978. Suicidal emergence and reproduction by overwintered pink bollworm moths. Environmental Entomology 7:189-192.

________ and T. J. Henneberry.
1980. Induction of diapause in field populations of the pink bollworm in the Western United States. Environmental Entomology 9:376-380.

Beatty, T.
1977. We need stub cotton research. Arizona Farmer-Ranchman 56:58.

Bergman, D., L. A. Bariola, and T. J. Henneberry.
1981. 1980 Boll weevil infestations in Arizona cultivated cotton. Proceedings of the Beltwide Cotton Production Research Conference, p. 70-75.

________ T. J. Henneberry, L. A. Bariola, and T. Watson.
1980. Cotton insect populations in Arizona stub cotton systems. Proceedings of the Beltwide Cotton Production Research Conference, p. 271-276.

Bishara, I.
1930. Ratoon cotton in relation to insect pests. Technical and Science Service (Plant Protection Section), Bulletin No. 96. Ministry of Agriculture, Egypt. 68 p.

Evanson, J. P.
1970. Ratooning of cotton: A review. Cotton Growing Review 47:1-7.

Flint, H. M., S. S. Salter, and S. Walters.
1980. Development of cotton and associated beneficial and pest insect populations in a ratoon field at Phoenix, Ariz. U.S. Department of Agriculture, Science and Education Administration, Agricultural Reviews and Manuals, ARM-W-15, 14 p.

________ R. L. Smith, and L. A. Bariola.
1976. Pink bollworm: Trap tests with gossyplure. Journal of Economic Entomology 69:535-538.

Foster, R. N., R. T. Staten, and E. Miller.
1977. Evaluation of traps for pink bollworm. Journal of Economic Entomology 70:289-291.

Fye, R. E.
1968. Populations of boll weevil in selected fields in Arizona in 1965 and 1966. Journal of Economic Entomology 61:377-380.

____
1976. Improved method of holding cotton bolls for detecting pink bollworms. U.S. Department of Agriculture, Agricultural Research Service, ARS W-37, 3 p.

________ and C. D. Bonham.
1970. Summer soil surface temperatures and their effect on boll weevil survival in fallen squares. Journal of Economic Entomology 63:1599-1602.

________ J. E. Leggett, and C. D. Bonham.
1970. Winter survival of the boll weevil complex in Arizona. Journal of Economic Entomology 63:1071-1074.

________ and C. R. Parencia, Jr.
1972. The boll weevil complex in Arizona. U.S. Department of Agriculture, Production Research Report No. 139, 24 p.

________ R. Patana, and W. C. McAda.
1969. Developmental periods for boll weevils reared at several constant and fluctuating temperatures. Journal of Economic Entomology 62:1402-1405.

Gillespie, J. M., T. F. Watson, T. J. Henneberry, and L. A. Bariola.
1979. A comparison of 1978 insect populations on stub and planted cotton in central Arizona. Proceedings of the Beltwide Cotton Production Research Conference, p. 99-103.

Leggett, J. E., and W. H. Cross.
1971. A new trap for capturing boll weevils. U.S. Department of Agriculture, Cooperative Economics Insect Report 21:773-774.

Rainey, R. C., and B. Smith.
1950. Cotton and its pests in South Africa. Ratooning as a threat to the revival of cotton growing in the Union. Union of South Africa Science Bulletin No. 308, 17 p.

Shiller, I.
1946. A hibernation cage for pink bollworm. U.S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, ET226, 6 p.

Slosser, J. E., and T. F. Watson.
1972. Population growth of the pink bollworm. Arizona Agricultural Experiment Station Bulletin No. 195, 32 p.

Taylor, B. B., and S. Hathorn, Jr.
1979a. A close, new look at stub cotton 12 years after the State ban. Progressive Agriculture, Arizona 17:12-13.

Taylor, B. B.
1979b. Pros and cons of stub cotton. Proceedings of the Beltwide Cotton Production Mechanization Conference, p. 25-26.

_______ and S. Hathorn, Jr.
1979c. Stub cotton in Arizona. Proceedings of Western Cotton Production Conference, p. 31-32.

_______ and S. Hathorn, Jr.
1981. Stub cotton in Arizona. A three-year program summary. In Cotton, College of Agriculture report. Arizona Agricultural Experiment Station, Series P-53, p. 21-23.

van Schaik, P. H., D. C. Erwin, and M. J. Garber.
1962. Effects of time of symptom expression of the leaf crumple virus on yield and quality of fiber of cotton. Crop Science 2:275-277.

Watson, T. F., K. K. Barnes, J. E. Slosser, and D. G. Fullerton.
1974. Influences of plowdown dates and cultural practices on spring moth emergence of the pink bollworm. Journal of Economic Entomology 67:207-210.

Wene, G. P.
1965. Cotton. In Cotton, a College of Agriculture report. Arizona Agricultural Experiment Station, Series P-1, p. 63-64.

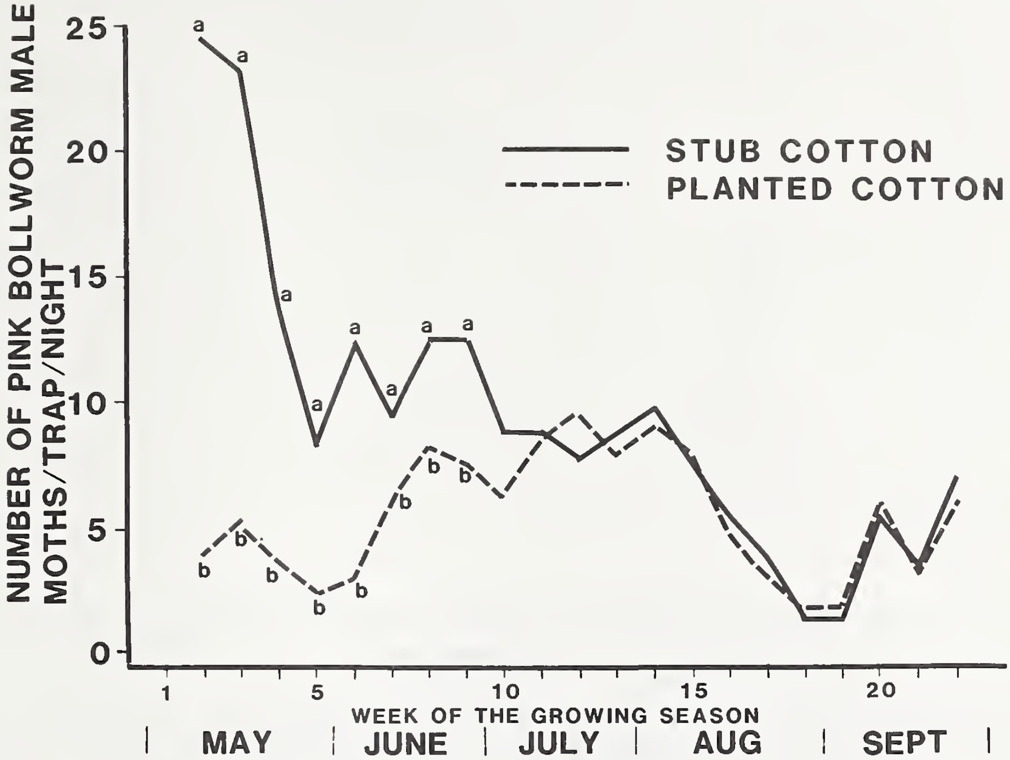


Figure 2.--Mean number of male pink bollworm moths caught per trap/night in stub and planted cottonfields in Arizona. (Means of 3 years--1978, 1979, 1980--for each data point. Means for each sampling date with different letters are significantly different, according to Duncan's multiple range test, P = 0.05.)

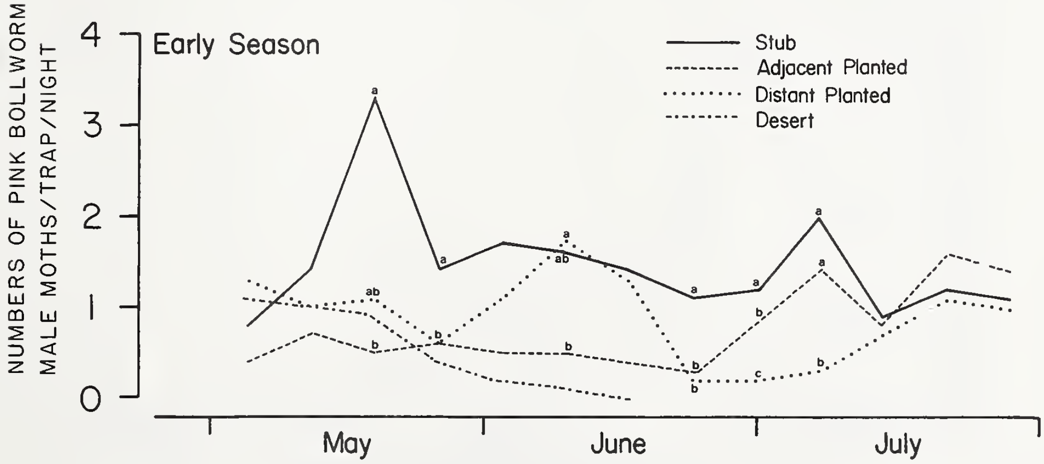


Figure 3.--Mean number of male pink bollworm moths caught per trap/night, May through July, in stub, adjacent and distant planted cotton, and in the Arizona desert. (Means of 2 years--1979, 1980--for each data point. Means for each sampling date with different letters are significantly different, according to Duncan's multiple range test, P = 0.05.)

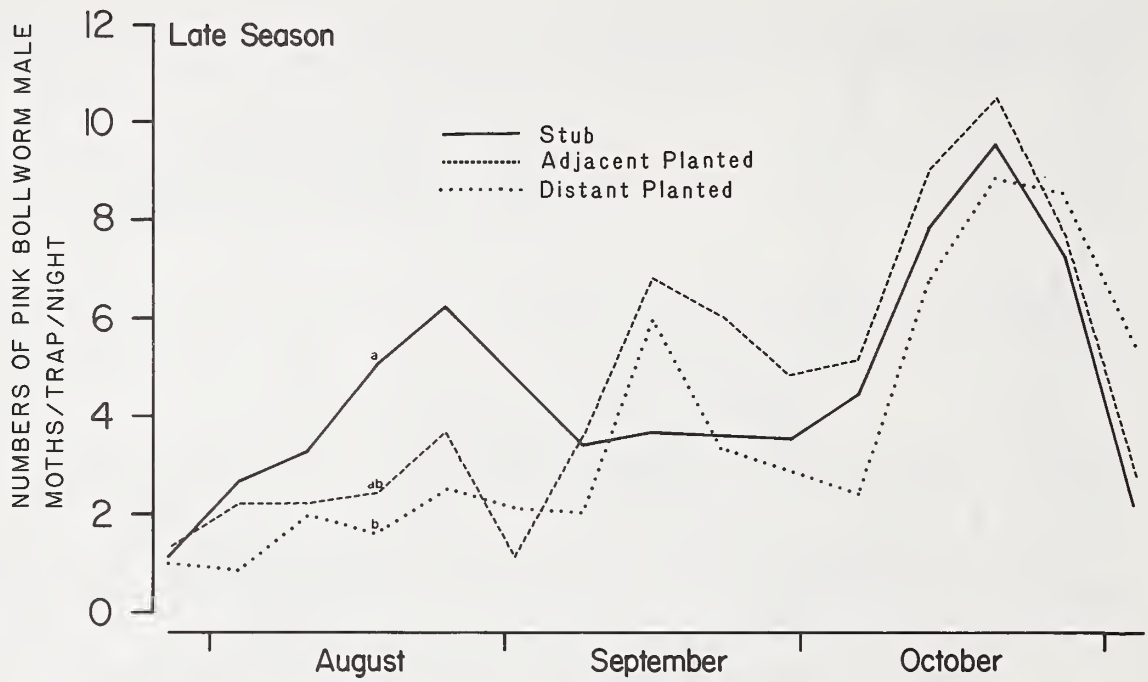


Figure 4.--Mean number of male pink bollworm moths caught per trap/night, August through October, in stub, adjacent and distant planted cotton in Arizona. (Means of 2 years--1979, 1980--for each data point. Means for each sampling date with different letters are significantly different, according to Duncan's multiple range test, P = 0.05.)

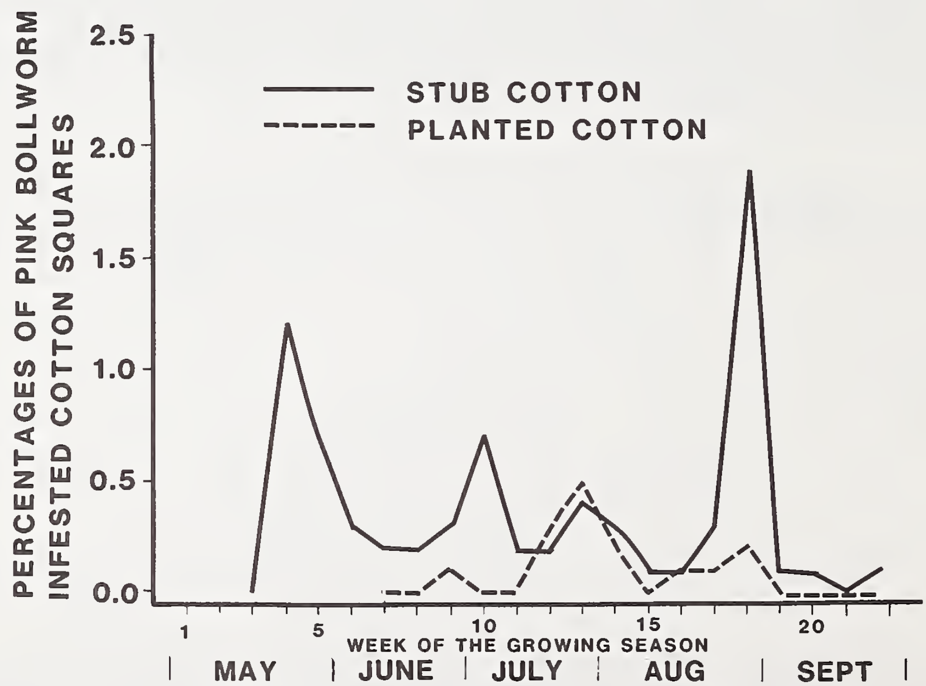


Figure 5.--Mean percentages of pink bollworm infested cotton squares in stub and planted cotton in Arizona. (Means of 3 years--1978, 1979, 1980.)

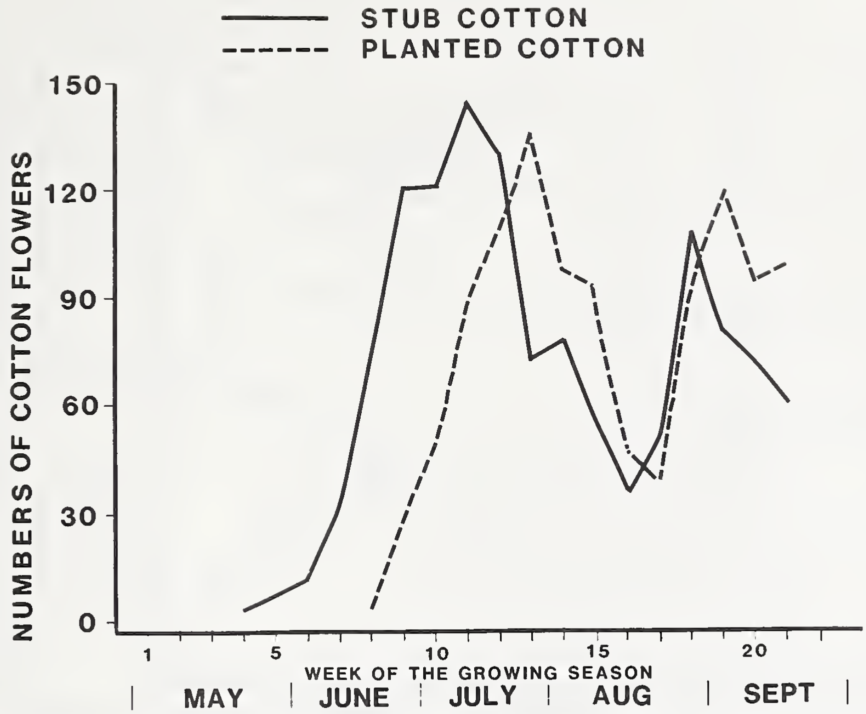


Figure 6.--Mean numbers of cotton flowers in stub and planted cotton in Arizona. (Means of 3 years--1978, 1979, and 1980.)

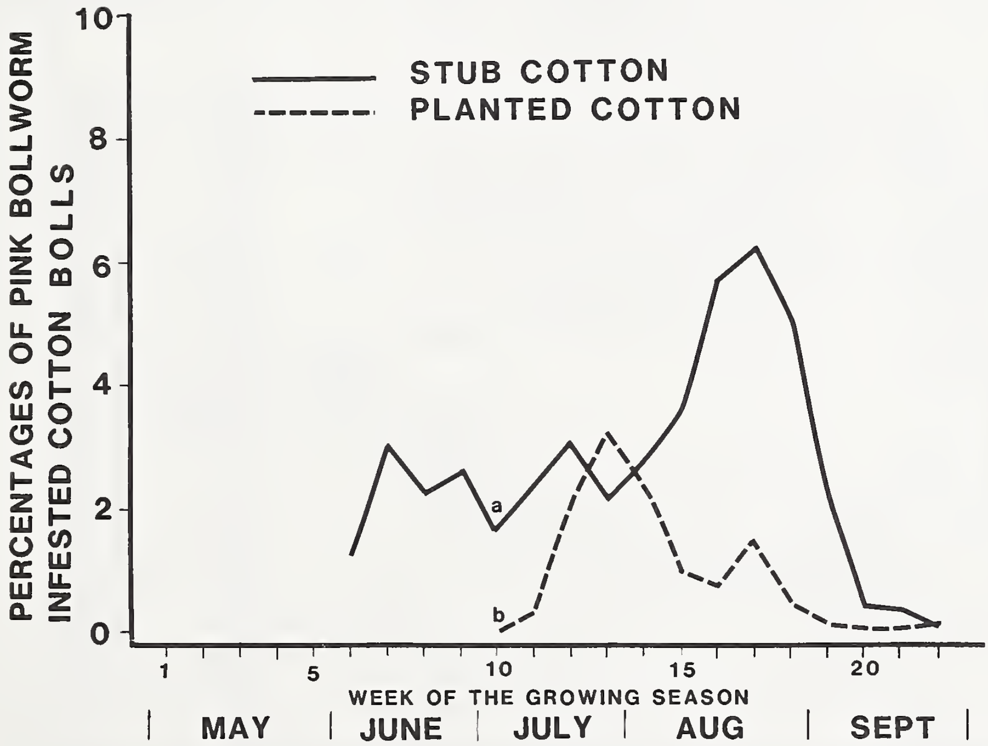


Figure 7.--Mean percentages of pink bollworm infested cotton bolls in stub and planted cotton in Arizona. (Means of 3 years--1978, 1979, and 1980.)

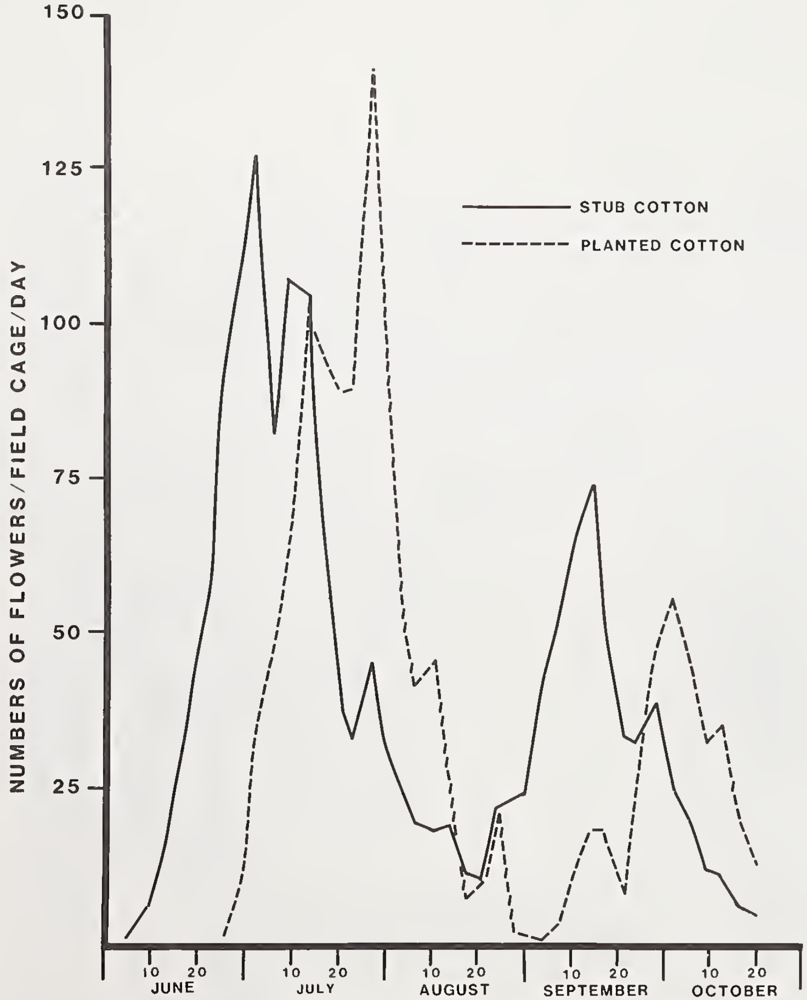


Figure 8.--Mean numbers of cotton flowers per cage per day over stub and planted cotton in Arizona. (Means of 4 replications.)

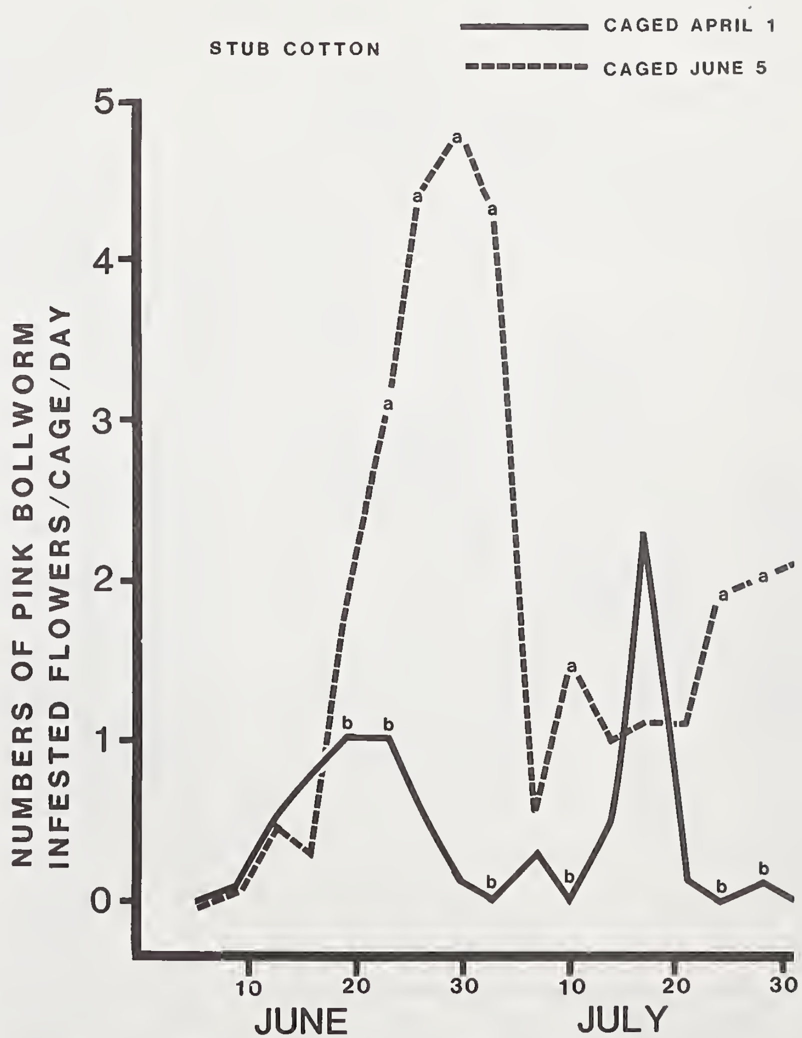
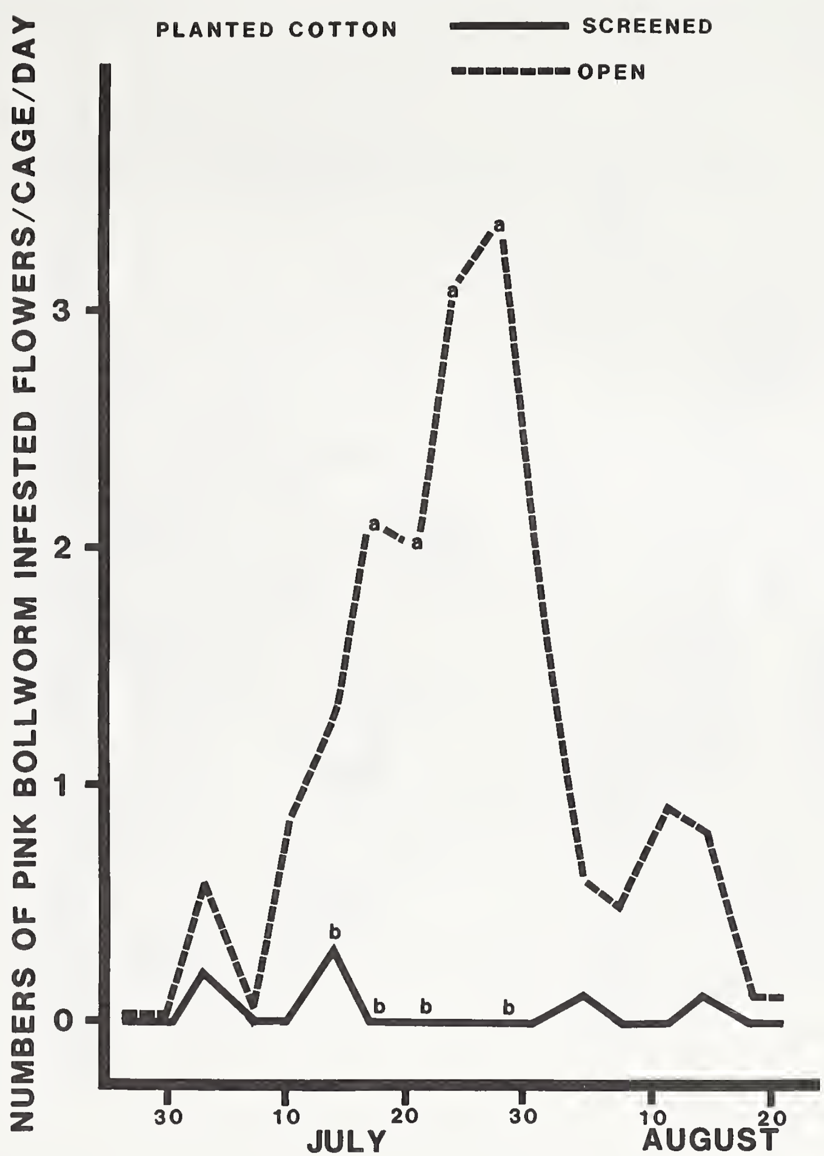


Figure 9.--Mean numbers of pink bollworm infested cotton flowers per cage per day. Cages placed over stub cotton April 1 and June 5. (Means of 4 replications. Means in the same sampling date with different letters are significantly different, according to Duncan's multiple range test, P = 0.05.)



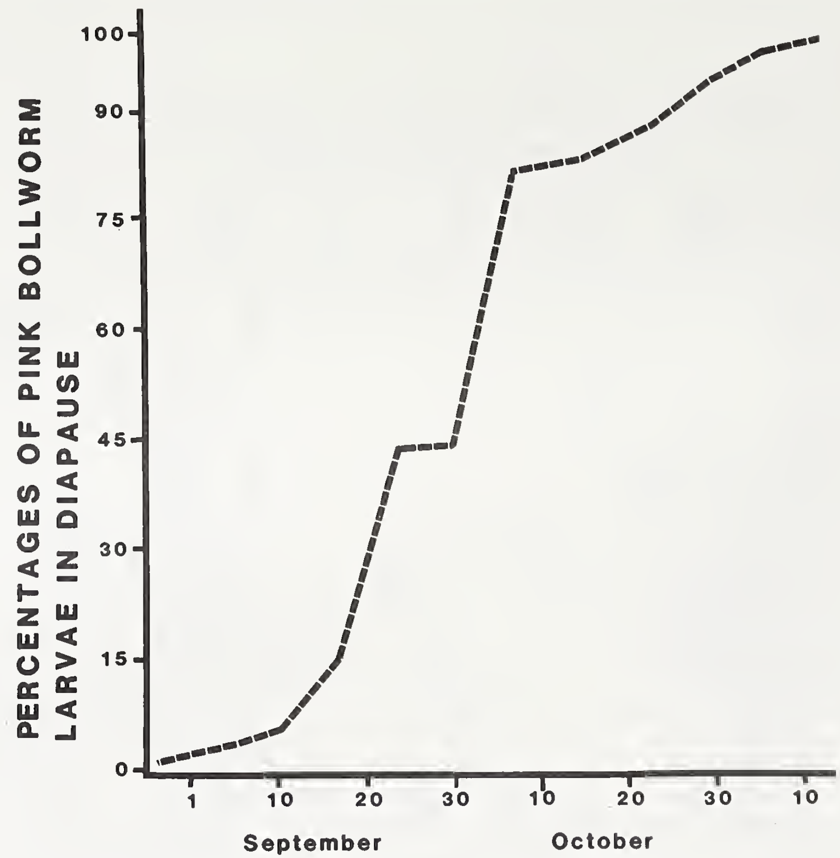


Figure 11.--Mean percentages of pink bollworm larvae in diapause in September, October, and November 1980 in Arizona.

Figure 10.--Mean numbers of pink bollworm infested cotton flowers per cage per day. Cages placed over planted cotton on June 4. (Means of 4 replications. Means on the same sampling date with different letters are significantly different, according to Duncan's multiple range test, P = 0.05.)

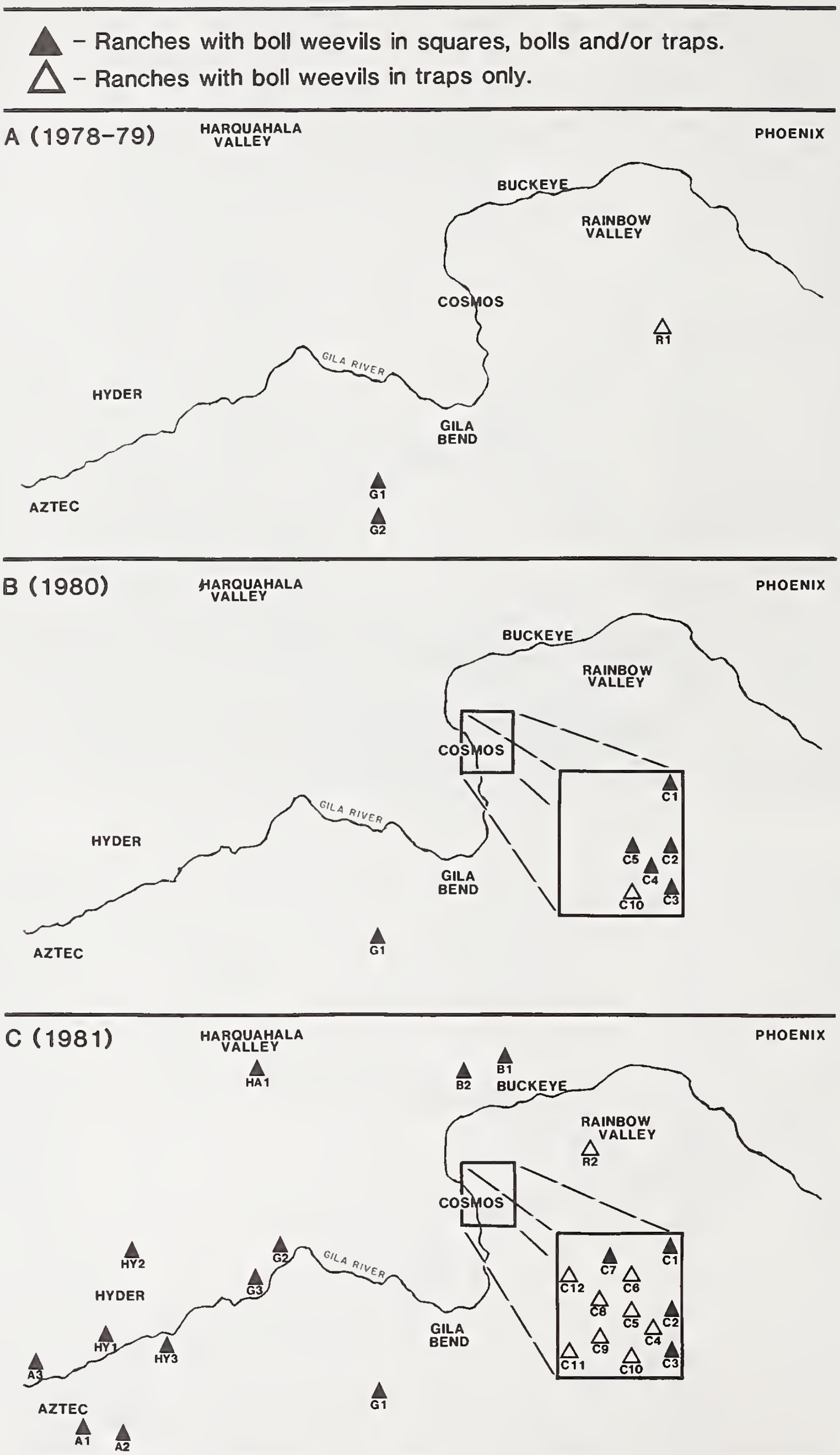


Figure 12.--Cottonfield locations showing spread and distribution of boll weevils found in squares, bolls, and/or traps in 1978, 1979, 1980, and 1981 in Arizona.

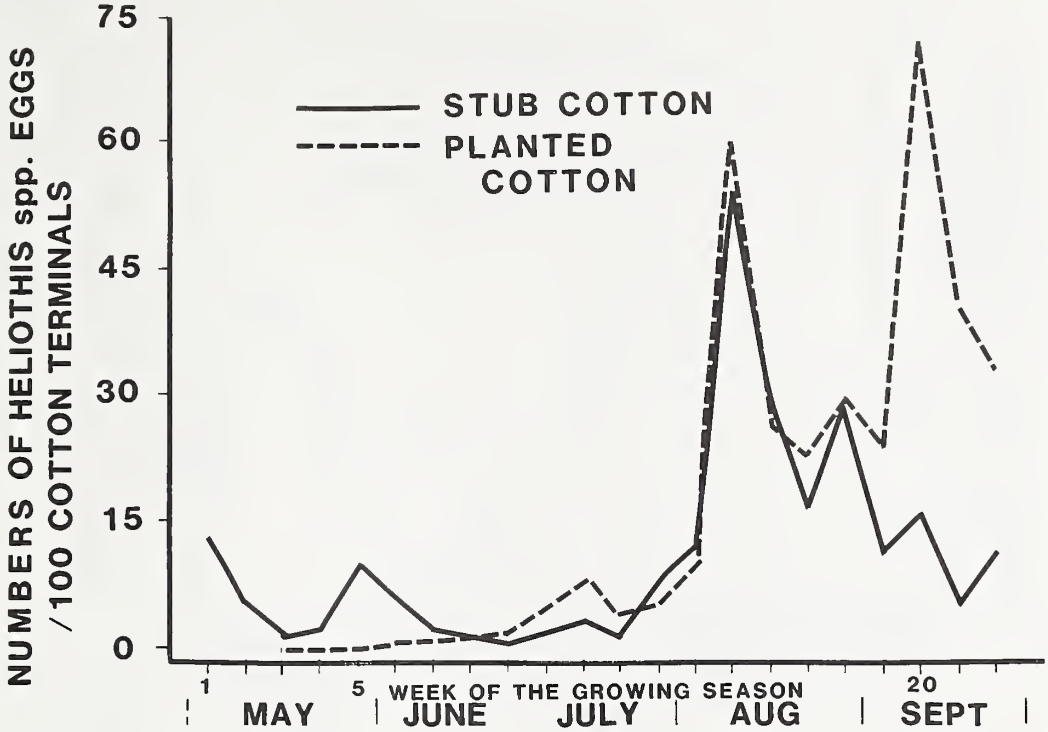


Figure 13.--Mean number of *Heliothis* spp. eggs per 100 terminals in stub and planted cotton in Arizona. (Means of 3 years--1978, 1979, and 1980.)

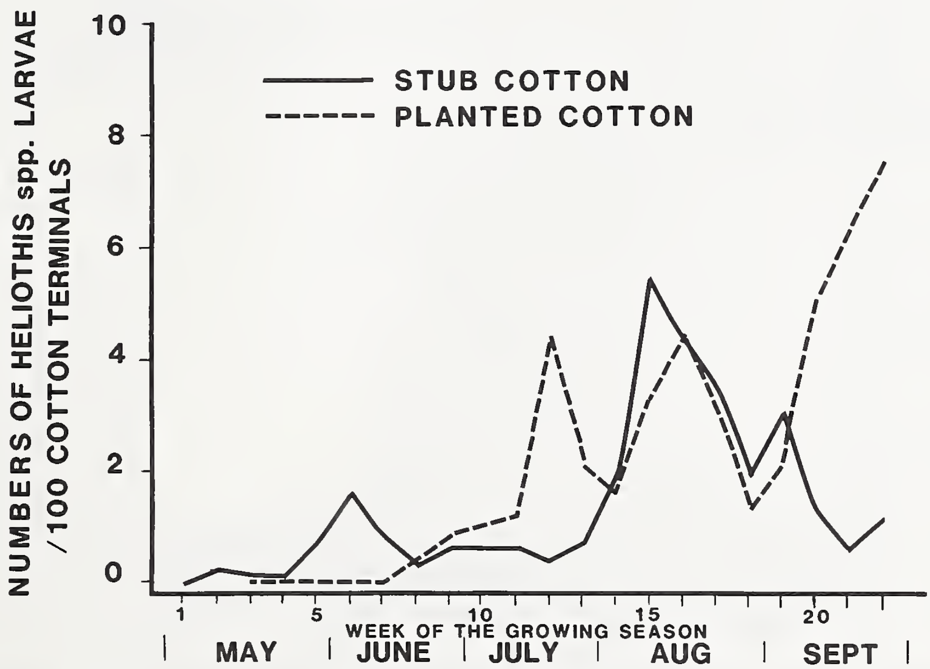


Figure 14.--Mean number of *Heliothis* spp. larvae per 100 terminals in stub and planted cotton in Arizona. (Means of 3 years--1978, 1979, and 1980.)

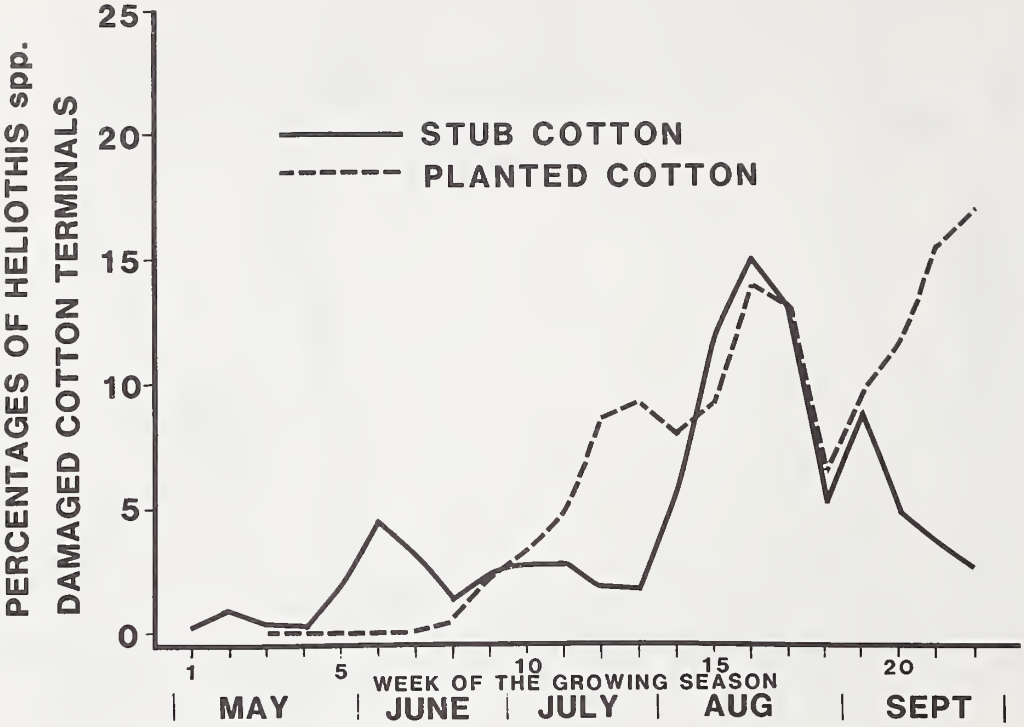


Figure 15.--Mean percentages of *Heliothis* spp. damaged terminals in stub and planted cotton in Arizona. (Means of 3 years--1978, 1979, and 1980.)

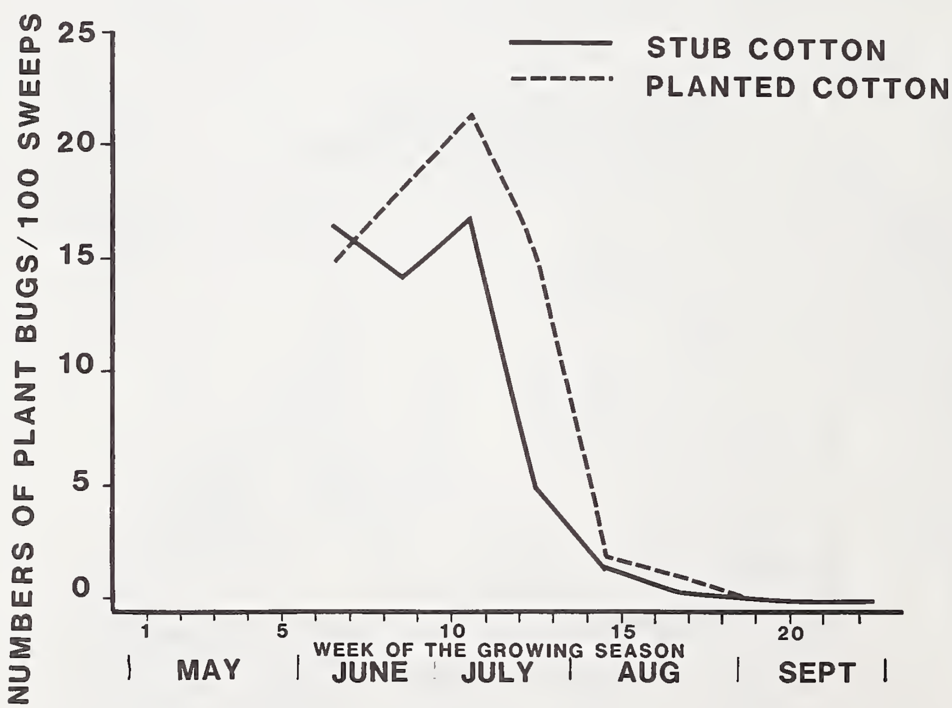


Figure 16.--Mean numbers of plant bugs per 100 sweeps in stub and planted cotton in Arizona. (Means of 3 years--1978, 1979, and 1980.)

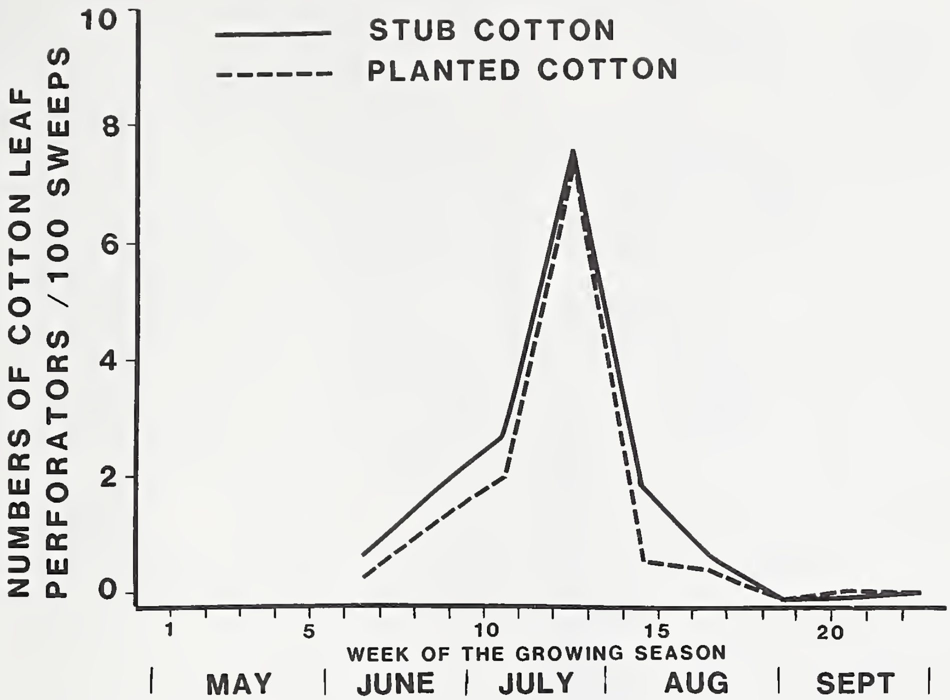


Figure 17.--Mean numbers of cotton leafperforators per 100 sweeps in stub and planted cotton in Arizona. (Means of 3 years--1978, 1979, and 1980.)

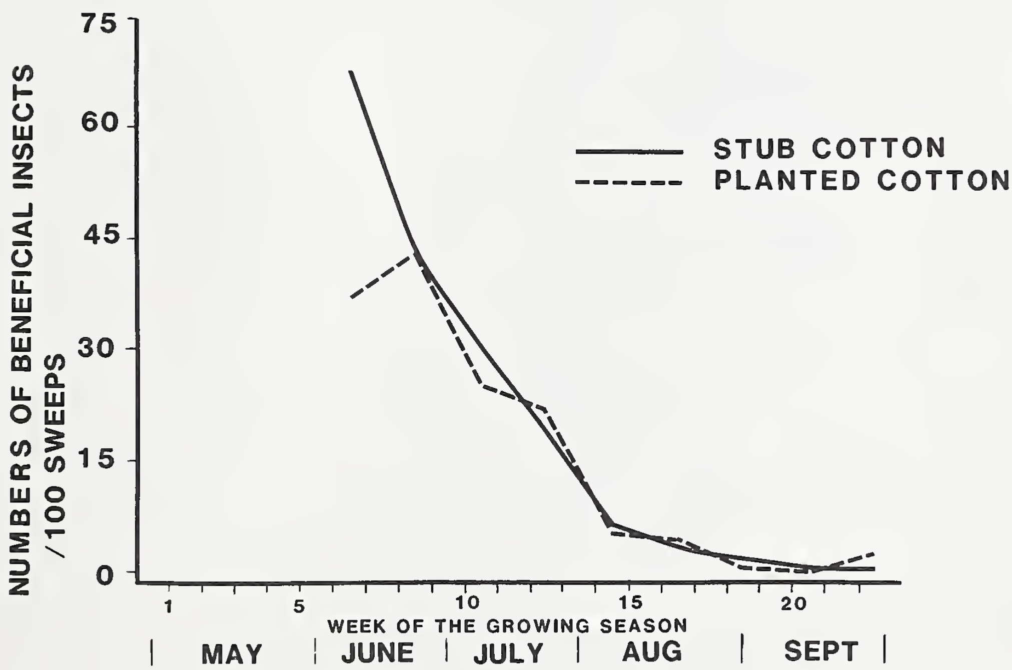


Figure 18.--Mean numbers of beneficial predators per 100 sweeps in stub and planted cotton in Arizona. (Means of 3 years--1978, 1979, and 1980). Includes *Orius*, *Geocoris*, *Nabis*, *Chrysopa*, Reduviidae, Coccinellidae, *Collops*, and spiders.)

U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
WESTERN REGION
1333 BROADWAY, SUITE 400
OAKLAND, CALIFORNIA 94612

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U. S. DEPARTMENT OF
AGRICULTURE
AGR 101

U.S.MAIL

PRINTED MATTER