STUDIES ON THE PINK BOLLWORM, *Pectinophora gossypiella* (Saunders), IN THE MESILLA VALLEY OF NEW MEXICO

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PREFACE

The status of the pink bollworm in New Mexico gradually changed from an infrequent pest of cotton in 1963 to a major pest in 1967. The unfeasibility of parts of the control program developed for central and south Texas and the failure of recommended cultural controls to reduce adequately pink bollworm populations in New Mexico prompted studies of control programs.

Preliminary results of trapping surveys in May, 1968, suggested that sticky trap height may influence the number of male pink bollworms caught. The height to which moths are attracted and trapped may also change during the season as the cotton grows. Studies were conducted in 1968 and 1969 to investigate the hypothesis that the trap height to which pink bollworm males are attracted changes as the cotton vegetation increases.

The absence of suitable long term control methods for the pink bollworm necessitated using insecticides as a short-term control measure. Extensive insecticide comparison trials were planned for 1968, but the pink bollworm again became a sporadic pest and this reduced the number of insecticide formulations compared. The Pneu-Mist ultra low volume sprayer used to apply the insecticide required several modifications to make it suitable for plot work.

Studies were conducted on the effects of irrigation, date, and depth of burial as related to temperature to determine the proper timing of effective cultural control measures to produce maximum mortality of overwintering pink bollworm larvae.

Data from a study conducted by Travis L. Pate of the Texas Agricultural Experiment Station at El Paso and a study by me at Las Cruces, New Mexico, suggested that cage size used to trap pink bollworm moths emerging from cultural treatments applied to overwintering larvae may influence the number of moths caught and possibly the interpretation of the treatment effects. A release-recapture study was run on a Shiller, Ellington, and modified Ellington cage, and the efficiency of the Shiller cage was compared with that of the Ellington cage for capturing moths emerging from simulated cultural treatments to test the hypothesis that cage sizes varied in trapping efficiency.

This thesis is divided into chapters, each of which contains a literature review where applicable, methods, results, and conclusions of the specific subject or area of study covered.

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CHAPTER I

DISTRIBUTION AND BIOLOGY OF THE PINK BOLLWORM

The pink bollworm, described in 1842 from specimens sent from Broach, India, to W. W. Saunders of Great Britain, was first named Depressaria gossypiella (order Lepidoptera: Gelechiidae). Later, the name was changed to Pectinophora gossypiella (Saunders) (Hunter, 1918). Subsequent reports of the pink bollworm came from German East Africa (Tanzania) in 1904, Egypt in 1906, and the Hawaiian Islands in 1909. In 1911, it was imported to Brazil and Mexico in cotton seed from Egypt, but the infestation in Mexico was not brought to the attention of the United States Government until 1916 (Scholl, 1919).

The first infestations in the United States were discovered in 1917 at Hearne and Beaumont, Texas, near oil mills which received several carloads of cotton seed from Mexico (Hunter, 1918; Scholl, 1919). Since that time, the pink bollworm has spread to all cotton-growing areas west of the Mississippi River and south of the 35° parallel except parts of California. It also has been reported in Florida but only exists in wild cotton at low levels. The most recent areas infested are in California's Imperial Valley in 1966 and the San Joaquin Valley in 1967 (Reynolds and Leigh, 1967; Spears, 1968).

The adult pink bollworm has an extended wing spread of 1.5 to 2.0 cm and resembles the common clothes moth. The moth is dark brown in color with irregular blackish markings on the forewings; the hindwings are silvery with no distinct markings. The forewings are bluntly pointed, and the hindwings are acutely pointed. Both pairs of wings are heavily fringed posteriorly (Hunter, 1918; Loftin et al., 1921).

Studies have indicated that the longevity of the adult depends on its environment and food source. The average length of life for the moths was 14.7 days when supplied with water and 7.6 days without water. The maximum length of life was 26 days with water (Loftin et al., 1921). In addition, the mean longevity of overwintering moths in cages with dry soil and no water was 3.1 days for females and 2.5 days for males. In cages with wet soil, the females lived an average of 8.7 days and the males 6.8 days. The maximum length of life was 19 days for females and 22 days for males (Owen and Calhoun, 1932). Supplying the moths with a cotton branch with leaves and young squares increased longevity of females from overwintering larvae to 11.6 days with a maximum of 24 days. Moths reared from green cotton bolls lived longer than those collected from squares (Fenton and Owen, 1953).

Mating studies indicate that the pink bollworm is a multiple-mating species, but the population present at any one time is mostly single mated (Ouye et al., 1964, 1965; Graham et al., 1965). A characteristic mating behavior of the males led Ouye et al. (1962) to investigate the possibility that the female released a mating attractant or stimulant. These investigators used methylene chloride to extract an attractant from whole females. Later, it was demonstrated that extracts from the terminal two or three abdominal segments of virgin female moths elicited a response in the males (Berger et al., 1964). Subsequently, Jones et al. (1966) isolated and synthesized propylure, 10-propyl-trans-5,9-tridecadienyl acetate, from the female.

Egg deposition is influenced by the food intake of the larvae and adults. More eggs were produced by moths reared from bolls than from squares (Fenton and Owen, 1953). Adults fed simulated cotton nectar laid more eggs than those fed water (Lukefahr and Griffin, 1956). The reproductive capacity of moths caged at regular intervals on cotton plants increased as the season progressed, even though all moths were obtained from diapause larvae (Brazzel and Martin, 1957). The maximum reproductive capacity is not reached until moths have a food source and the female moths have fed in bolls during the larval stage (Adkisson, 1961a).

Pink bollworm eggs are elongate oval and somewhat broader at one end. They are 0.4 to 0.6 mm long and 0.2 to 0.3 mm wide. The eggs have a pearly white, iridescent shell with a greenish tint when first deposited and turn to almost red before hatching.

Oviposition does not begin before the second night after adult emergence, with the greatest number of females beginning to lay the third night after emergence. Oviposition was not observed until near dark, with the greatest number of eggs being laid the first 2 hr after dark. The number of eggs laid decreased progressively through the night (Owen and Calhoun, 1932). Eggs are laid singularly or in groups of one to four, with as many as 20 being found in a group (Busck, 1917). In early season, eggs are laid on terminals and other vegetative parts, but after bolls appear 30 to 50% are deposited on the bolls. When there are approximately 12 bolls per plant, over 50% are laid on the bolls (Brazzel and Martin, 1957; Lukefahr and Griffin, 1957). Owen and Calhoun (1932) reported that moths emerging from overwintering diapausing larvae laid an average of 105 eggs with a maximum of 289 and summer moths deposited an average of 180 eggs with a maximum of 448.

In Mexico, the mean time required for hatching was 4.6 days (Loftin et al., 1921) and in southwestern Texas, 4.5 days at a mean temperature of 28.3 ° C (Owen and Calhoun, 1932). Adkisson (1959) demonstrated that the greatest percentage of eggs hatched at 75 and 100% relative humidity. Over one-half of the eggs exposed to 0 and 45% relative humidity hatched, indicating the humidities normally occurring in the field probably would not greatly retard pink bollworm infestations.

Larvae are active after hatching but will die if they do not find a fruiting body within 1 or 2 days (Fenton and Owen, 1953). Also, the larvae are cannibalistic and avoid contact with one another whenever possible (Brazzel and Martin, 1955). In the early season, larvae cut their way into squares and feed on the immature anthers. According to Fenton and Owen (1953), larval development in squares required 6 to 18 days with a mean of 10 days. The infested bloom usually has the tips of the petals webbed together so that it will not open, giving the bloom a rosette appearance. The larvae develop in blooms without causing abnormal development of the boll. Bolls are approximately 20 days old before being fed upon. Larvae sometimes tunnel in the boll wall before entering the lint and seeds upon which they feed (Ohlendorf, 1926). In bolls, the developmental time was 11 to 25 days with a mean of 16.5 days (Fenton and Owen, 1953). Lukefahr and Griffin (1962) found that the developmental rate was faster in squares than in bolls.

Pupation of the early and mid-season larvae occurs in the plant debris, soil, or around the base of the cotton plant. The pupal stage lasts from 6 to 24 days, with a mean of 8 days (Fenton and Owen, 1953).

Near the end of August, some pink bollworm larvae do not pupate, but enter diapause. Diapausing pink bollworm larvae overwinter in cotton bolls or seeds and as free cocoons in plant debris or the soil. Diapause in the pink bollworm is regulated by a multigenic character with a high titer of genetic factors required to cause larval diapause under conditions favorable for continued development and a low titer required to induce diapause if conditions are unfavorable for continued development. It does not tend to be dominant nor is it sex-influenced (Barry and Adkisson, 1966). Diapause is induced by photoperiod and the response is modified by boll age or diet and temperature. Larvae reared on diets or older bolls having a higher lipid content enter diapause more readily than larvae reared on low lipid diets (Adkisson, 1961b; Adkisson et al., 1963a; Lukefahr et al., 1964). At 26.7° C, diapause is initiated at 13 hr of light, and the percentage of diapausing individuals increases with decreasing photophase (Adkisson et al., 1963a). A higher incidence of diapause occurred when the eggs were subjected to a 12-hr inductive photoperiod rather than to constant light (Adkisson and Bell, 1964; Menaker and Gross, 1965). A higher incidence and a more intense state of diapause occurred when larvae were reared under fluctuating temperatures as opposed to being reared under constant temperatures equal to the mean of the fluctuating temperatures (Menaker and Gross, 1965). A strain of larvae from El Paso (latitude 32° N) showed a higher incidence of diapause than strains from lower latitudes (Ankersmit and Adkisson, 1967).

Termination of diapause is influenced by physiochemical conditions. Field and laboratory studies indicate that moisture stimulates pupation of diapausing larvae (Chapman et al., 1960; Fife, 1961; Richmond and

Clark, 1965). At 26.7° C and 14 hr of photophase, diapause is terminated more rapidly under 100% humidity than under 65% humidity. High ambient temperatures and humidities shift the response curve so that termination of diapause occurs faster when a day length exceeding 13.25 hr is reached. Conversely, relatively low temperatures and humidities shift the curve so that a longer period of time is required to obtain 100% termination of diapause, even at the proper day length (Wellso and Adkisson, 1964). In New Mexico, moth emergence from overwintering larvae usually occurs from April to September with the majority emerging from mid-May to late June.

Shiller et al. (1962) summarized host-plant studies of the pink bollworm in the United States and northern Mexico. Cotton (Gossypium spp.) is the preferred host and okra (Hibiscus esculentus L.) is probably second. Wild hosts and ornamentals exert only a negligible influence on populations of the insect but may be important in an eradication program. In addition to plants of the genus Gossypium, 46 species belonging to the Malvaceae, Euphorbiaceae, Leguminosae and Convolulaceae families are listed as hosts for the pink bollworm in North America.

CHAPTER II

ULTRA LOW VOLUME (ULV) APPLICATION OF INSECTICIDES TO CONTROL THE PINK BOLLWORM

Since pink bollworm populations gradually increased in New Mexico during 1965 and 1966 and caused widespread economic losses in 1967, it was necessary to use insecticides as a short-term control measure until more suitable control methods could be developed. In the present study, insecticide trials were conducted in 1968 to evaluate several insecticide formulations applied by ground equipment as ULV sprays.

Materials and Methods

An 8-row Pneu-Mist ULV sprayer (Magnolia Agricultural Supply, Jackson, Miss.) was used in this study. The ULV boom was mounted on the conventional sprayer boom of a high-clearance tractor. For easy access, the gasoline-powered air compressor was mounted on a small platform on the rear of the tractor. The control panel was mounted next to the operator's seat, and the insecticide holder and pump were mounted on top of the tractor platform.

It was necessary to adapt the sprayer for plot work. The 9.4-mm polyethylene hose that connected the insecticide container, pump, and control panel to the boom was replaced with 6.4-mm hose. This reduced the amount of insecticide necessary to fill the system and the time required to clean the hose and boom. The 12-volt 0.1-hp motor of the spray system was rewired to allow the four-roller pump to be driven in either direction. The Pneu-Mist nozzles were equipped with diaphragm check valves made by Spraying System. The spring-backed internal diaphragm assembly shut off liquid to the nozzle when the pump was stopped, thus preventing dripping. Since liquid could not be pumped back out of the boom because of the vacuum created, ammonia backflow check valves that closed under pressure and opened under suction were installed on the ends of the spray booms and a bypass cutoff was installed around the regulator to allow backflow. These modifications allowed most of the insecticide to be pumped back into the original container. This greatly reduced the amount of concentrated chemical washed onto the ground by the solvent used to clean the system between different insecticide treatments. A 6.4-mm hose barb was installed in the bleed-off orifice of the air regulator. The uptake hose was placed on the barb, and the remaining solvent was purged from the system with air. This prevented dilution of the remaining insecticide treatments.

The arrangement of the needle valve and regulator was found to be unworkable. A small movement of the needle valve changed the line pressure drastically and made it difficult to adjust to a different pressure. The line pressure was also erratic. The needle valve on the control panel was interchanged with the regulator near the pump. By placing the regulator on the control panel near the pressure gauge, a steady line pressure was maintained and the time required to calibrate the machine or to adjust it for a new setting was reduced.

An air hose 1 m long with an attached blow gun was installed on the air system of the Pneu-Mist sprayer to facilitate cleaning of clogged nozzles.

Pink bollworm infestations were light and spotty in 1968. An infested cotton field suitable for spraying was not located until the last of July. Although Adkisson et al. (1963b) reported that economic losses begin to occur when boll infestation exceeds 22%, the treatments were started in late August when the mean infestation was 10.5% since only the effectiveness of the chemical was being tested. Since only one-half of the field was infested with enough pink bollworms for control evaluation, only the following three insecticides or insecticide mixtures were used: (1) azinphosmethyl (Guthion LC^{R}); (2) azinphosmethyl, 449g, + azinphosethyl, 449g, + methyl parathion, 359g/liter (Guthion M-E-methyl parathion), and (3) azinphosmethyl, 90g, + azinphosethyl, 90g, + parathion, 330g/liter (Co-Thion^{R}). The rates applied per hectare are shown in Table I (Appendix A).

The experimental design was a randomized complete block with five treatments and four replications (Table I). Acala 1517D cotton was planted in rows 1 m apart, with 44 rows to an irrigation border. A strip 4 m wide between each 44-row border was kept free of vegetation. Since an eight-row plot is the most commonly used plot size in insecticide evaluation trials applied by ground equipment in cotton, four borders were divided into five eight-row plots. Two rows were left untreated on each side of the border. Rows ran east and west and averaged 189 m long.

On the day preceding insecticide application, infestation levels were determined from 100 boll samples picked at random from the middle third of the cotton plants in the middle four rows of each plot. The bolls were cracked with an apparatus similar to the one described by Clark (1957), and the number of bolls infested with one or more larvae was recorded.

Insecticide applications were made early in the morning when wind was insignificant on September 12, 18, 24, and 30. The air pressure used to atomize the spray and carry it to the plant was 3.6 kg, which is considered by the manufacturer of the Pneu-Mist sprayer to be the optimum pressure for minimum drift and maximum plant coverage.

Results and Discussion

The modifications made on the Pneu-Mist sprayer greatly reduced the time required to clean the spray system and change to another insecticide. The amount of chemical required per application was reduced nearly one-half. Little concentrated toxicant was washed onto the ground with the cleaning solvent. This, in itself, is a significant improvement over the unmodified sprayer.

In the plots, the percentage of bolls infested with pink bollworms increased after the first insecticide application (Table I). This probably was due to not observing some of the first instar larvae not affected by insecticide treatments on the first sampling date. The larvae were larger and easier to find on the second sampling date.

The data were analyzed in two ways. An analysis of variance was run using data from all sampling dates (Table II). The five treatment effects were not statistically significant at the .01 level, but the effects due to dates of sampling and replications were significant. The second analysis of variance was done using data obtained by subtracting the pre-treatment data of each plot from post-treatment data (Table III).

Using the differences from the pre-treatment counts lowered the variation among replications, and only dates of sampling showed significant effects at the .01 level. The mean infestation changed during the period when treatments were applied; however, the decreases at the end of the study were not due to chemical treatment, but resulted from the exit of the fourth instar larvae from the boll to overwinter or to pupate.

Adkisson et al. (1958) and Watson et al. (1968) reported that conventionally applied azinphosmethyl controlled pink bollworms. In the present study, the absence of no differences in the treatment effects may be due to drift of the ULV-applied chemicals. The smaller of the ULV spray particles do not immediately settle on the cotton plants, making particles susceptible to air movements that occur during application. Plots for evaluation of ground-applied ULV insecticides should be larger to minimize effects due to chemical drift.

The lack of significant differences due to treatments may have been influenced by the low night temperatures during insecticide application. From September 11 through 30, the maximum day temperature varied from 28.3 to 31.7° C and averaged 30.0° C. The minimum night temperature varied from 5.6 to 14.4° C and averaged 10.3° C. Graham et al. (1967) found that pink bollworms reared under constant temperatures of 18.3 or 21.2° C had a low fecundity rate and a prolonged reproductive period, and that a constant temperature of 15.6° C was unfavorable for reproduction. Phillipp et al. (1971) reported that pink bollworms reared under a 24-hr temperature regime of 10 hr at 14.4° C and 14 hr at 32.8° C had a lower reproductive rate than when the minimum was raised and the maximum was 36.7° C. Phillipp et al. also found that reproduction was sharply reduced when temperatures during scotophase were below 21.2° C. Thus, oviposition in the present study may have been reduced by low night temperatures which precluded an infestation increase even in the check.

CHAPTER III

EFFECT OF TRAP HEIGHT ON CATCHES OF PINK BOLLWORM MALES IN STICKY TRAPS BAITED WITH SEX LURE

In May of 1968, sticky traps were baited with sex lure to determine presence and distribution of the pink bollworm. At that time, it was observed that most moths were caught in sex-lure traps 15 to 30 cm in height and that traps on the ground or 90 cm above ground caught few or no moths. These observations prompted studies in 1968 and 1969 to investigate the relationship of the catch of pink bollworm males to trap height and the changing height of the cotton plant during the growing season. More specifically, these studies were designed to investigate the hypothesis that the trap height to which pink bollworm males are attracted changes as the cotton vegetation increases.

Methods and Materials

In the 1968 study, the experimental design was a randomized complete block with three treatments and five replications. Two 40-row borders of cotton planted in rows 1 m apart separated each replication. Treatments used to define the effects of trap height were one trap set at 15 cm above the ground, one trap at 61 cm above the ground, and a pair of traps 15 and 61 cm in height set on the same rod. Traps were suspended horizontally from 1-m metal rods with string. The rods, with traps attached, were placed approximately 2 m from cotton in irrigation borders 182 m long and 4 m wide. The traps were placed at 45.7, 91.4, and 45.7 m from the ends of the cotton field (Figure 1, Appendix B).

Male moths attracted by the sex lure were caught in a modified Frick trap. This consisted of a .95-liter ice cream container, 11.4 X 17.8 cm, with a 1.9-cm hole in each end and coated inside with Stickem[R]. A heavy, white filter-paper pad, 2.5 X 7.6 cm, was secured in the top center of the trap by a double-pronged hairclip. The Plant Protection Division of the U. S. Department of Agriculture furnished a methylene chloride extract of the female pink bollworm which contained 6 female equivalents (FE) per cc for use in this study. A hypodermic syringe was used to place the sex lure extract on the pad. Two cc of 6 FE were used in single traps, and 1 cc per trap was used in the double trap treatment.

Traps were checked daily and the pink bollworm moths removed. Since the lure lost its effectiveness with time, all traps were rebaited at intervals of three or four days. Heights of cotton plants in the five replications were measured on the same date that traps were baited.

The 1968 study was limited to June 7 through July 29 due to the shortage of the natural sex lure extract of the female. Since data from the 1968 study suggested that cotton height influenced the number of pink bollworm moths caught in sticky traps, a 1969 study was conducted to determine (1) the relationship between trap height and height of cotton during the growing season, and (2) the relationship between concentration of sex lure and moth catch.

Traps were placed in cotton fields in the rows rather than outside the cotton vegetation in irrigation borders as in the 1968 study. Rows were 1 m apart. Six treatments were replicated in four different fields less than 1.6 km apart. Treatments were (1) one set of 15 and 91 cm high traps per rod with 5 mg of hexalure per trap; (2) one set of 15 and 91 cm high traps per rod with 10 mg per trap; (3) one 15 cm high trap with 10 mg; (4) one 15 cm high trap with 20 mg; (5) one 91 cm high trap with 10 mg; and (6) one 91 cm high trap with 20 mg. Thus, three trap sets received 10 mg of hexalure and three received 20 mg. The traps were placed approximately 42 m apart in the twentieth row of cotton of the forty-row borders.

A modified Frick trap was used and suspended as in the 1968 study. However, a synthetic sex attractant for pink bollworm males, cis-7-hexadecene-1-ol-acetate (hexalure), was substituted for natural sex lure extracts of females because it was reported to be more chemically stable, less susceptible to microbial decomposition, more effective in the field for a longer period of time, uniformly more potent, and less expensive than natural lure extractions (Keller et al., 1969). A solution of 10 mg of hexalure per cc of acetone was mixed for use in baiting the traps during the present study. Traps were baited, and the captured male pink bollworm moths were counted and removed every seven days. Also, heights of cotton plants in the four fields were measured every seven days.

Results and Discussion

Trap catches indicated that the 1968 peak emergence of overwintering populations of male pink bollworms occurred during the third week of June (Table IV, Appendix A). At this time, squares were available for pink bollworm propagation. The catch during the early sampling dates was greatest in the single 15 cm high traps, while the single 61 cm high traps caught the smallest number of male bollworms (Figure 2). Toward mid-season, when the cotton was approximately 68 cm tall, more moths were captured in the treatment having two traps per location. However, single 61 cm high traps caught more moths near the end of the study when the cotton plant averaged 84 cm in height. These data indicate that traps near cotton should be set 15 cm above the ground until the cotton attains 61 to 71 cm in height and then maintained at a 61-cm height.

In 1969, peak emergence of male moths from overwintering larvae occurred in early June (Table V). Catches of the first generation began to occur five weeks after peak moth emergence from overwintering but did not reach a peak until eight weeks later. Data from Fenton and Owen (1953) indicates the pink bollworm has a generation length of approximately five weeks in the Las Cruces area of New Mexico (Mesilla Valley). The observed time lag between population peaks indicates that reproduction by the overwintering generation may have been more effective in early July, even though squares were available during peak emergence in mid-June. This contention was supported by Brazzel and Martin (1957), who reported that moths emerging from overwintering from June 1 through 21 had a lower reproductive rate than moths emerging from June 22 through July 20. Since eggs are laid mainly on terminals and vegetative parts in early season before bolls become available, considerable mortality of larvae searching for squares as food may occur. From limited field observations of pink bollworm larvae in fallen cotton blooms in the Mesilla Valley, considerable larval mortality appears to occur before bolls are available for larval food. Any one or a combination of these factors could increase the time between generations, thus reducing the number of generations per year and lowering the probability of population increases in New Mexico.

With the three paired treatments receiving 10 or 20 mg of hexalure per location, the larger concentration caught 1.72, 1.80, and 2.02 times as many moths as the smaller concentration (Table V, Figures 3 and 4). Keller et al. (1969) caught 1.4 to 2.1 times as many moths by doubling the concentration of hexalure.

The most moths were caught in traps at 15 cm when the cotton was small and in traps at 91 cm when cotton reached 51 to 66 cm (Figures 3 and 4). The relationship between cotton height and catch is probably due to interference with the movement of the sex lure by cotton vegetation after the plant height reaches about 46 cm. If traps were set 15 cm above the ground in rows less than 76 cm apart, this effect would probably appear sooner. Trap height, then, should be maintained at or near the top of the cotton vegetation, especially after the cotton plant height exceeds 46 cm.

Analysis of variance run on the 1969 data revealed that weeks, treatments, and weeks-by-treatment interaction effects were significant ($P = .01$) (Table VI). The number of moths caught per week at the two trap heights changed as the pink bollworm population fluctuated and as the cotton increased in height with time, resulting in an interaction between weeks and trap heights.

These results show the importance of proper height placement of sticky traps baited with sex lure for controlling or surveying populations of pink bollworm moths. Improper height placement of traps could hinder the detection of low density populations and lessen the prospects of maximum control. Results also show that the catch of male pink bollworm moths was increased by increasing the concentration of hexalure from 10 to 20 mg.

CHAPTER IV

EFFECTS OF TEMPERATURE, IRRIGATION, DATE, AND DEPTH OF BURIAL ON OVERWINTERING PINK BOLLWORM LARVAE

In the arid southwestern United States, the first studies to determine the effects of burial and irrigation on mortality of overwintering pink bollworm larvae were conducted at Castlelon, Texas, from 1927 to 1928 and at Presidio, Texas, from 1928 to 1931 by Fenton and Owen (1931, 1953) and Isler and Fenton (1931). Their results indicated that a lower survival rate resulted from deeper burial and burial immediately followed by an 18 cm irrigation. Burial in December and January when not followed by an irrigation increased the survival rate. The most effective cultural control was a combination of late spring burial immediately followed by an irrigation.

Surveys and studies have been conducted on the pink bollworm since its introduction in 1920 into the El Paso, Texas - Las Cruces, New Mexico, area. Surveys were conducted until 1940 to determine the extent of infestations. Small scale experiments during 1940-44 verified that the pink bollworm overwintered in the area. Pink bollworm survival and time of emergence under different conditions simulating various cultural practices were studied from 1944 to 1952 by Noble (1955). In his studies, survival in the 5 to 10 cm burial on December 15 was less than in the March 15 burial. Survival was lowest in bolls on stalks standing throughout the winter and then buried. More than 50% of the buried larvae emerged suicidally or before cotton was sufficiently advanced for their propagation while 93% of those on the surface emerged non-suicidally. Noble (1955) also stated that the overwintering of larvae in free cocoons outside of the cotton boll was of minor importance. His studies did not include burial deeper than 10 cm, nor were any winter irrigations applied.

Temperature and soil moisture affects survival of pink bollworm larvae. Richmond and Clark (1965) reported that in laboratory studies using constant temperatures of 8.3, 28.9, and 37.8° C in combination with soil moistures of air dry, one-half field capacity, and field capacity, high soil moisture and high temperatures produced the greatest mortality. At first, low temperatures and dry soil appeared to have the least effect on larvae, but mortality increased under continued dry, cold conditions. The best survival was at 28.9° C under one-half field capacity (Richmond and Clark, 1965). Mortality from cold temperatures appears to be influenced not only by the extreme minimum but also by the duration of temperatures below 4.4° C, and some moisture is necessary for pupation and emergence in the spring (Chapman et al., 1960).

Results from some studies conducted on the pink bollworm in Arizona conflicted with results of research done in the less arid regions of the country. In Graham County, Arizona, 50% or more of the pink bollworm larvae overwintered as free cocoons rather than in the seed or boll. A 15 cm burial of bolls, especially in winters of low rainfall, did not give adequate reduction of overwintering larvae as measured by spring moth emergence (Wene et al., 1965; Wene and Sheets, 1966). Rauschkolb and Pearson (1968) found that tillage on December 14 appeared to protect the larvae since more moth emergence was recorded from burial on this date than where the soil was not disturbed. In two treatments, all debris was removed after the stalks were shredded; therefore, the emergence was from larvae overwintering as free cocoons.

Conflicting results suggest that a change in timing of control practices or a different combination of treatments may be required for control of the pink bollworm under the climatic conditions of the arid southwest. This was further substantiated by the failure of the cultural control program developed for central and south Texas to give satisfactory results when used by growers in New Mexico.

Widely separated experiments in Texas and Oklahoma showed that spatial variation in pink bollworm survival existed under winter cultural practices primarily due to climatic conditions (Chapman et al., 1960). At Las Cruces, New Mexico, winter rainfall (December, January, and February) varies from a trace to 8 cm and averages 3.28 cm; spring rainfall (March, April, and May) varies from a trace to 7.5 cm and averages 2.0 cm. In many years, the lack of winter moisture to decompose plant debris in overwintering sites combined with a pre-plant spring irrigation which stimulates pupation is believed to result in greater pink bollworm survival in New Mexico.

Effects of irrigation, depth, and date of burial on overwintering survival of the pink bollworm in the Mesilla Valley of New Mexico is not known. An experiment was conducted to study the effects of various simulated cultural practices on survival of overwintering pink bollworm larvae under the geo-meterological conditions present in New Mexico. Three depths of burial were selected which simulated shallow plowing, deep disking or inadequate plowing where stratification of overwintering sites occurs, and deep plowing where the soil is turned over to bury overwintering sites of the pink bollworm consistently deeper than 15 cm. The irrigation treatments represented three field situations which may occur in this area: (1) cotton fields receiving no irrigation, minimum tillage, and left fallow as part of a farmer's rotational program; (2) cotton fields having low soil moisture during the winter and a pre-plant irrigation in early spring; and (3) cotton fields receiving rainfall and the normal pre-plant irrigation to maintain the soil moisture content at a high level during the winter and spring. The four dates of burial encompass the time in which cotton fields are tilled. Moths which emerge suicidally do so without contributing towards an increase in the population, thus the time of emergence was included as a factor in the study.

Soil and air temperatures were recorded to investigate the possibility of a relationship between the cultural treatment effects and temperature. Knowledge of temperature and cultural treatment relationships would allow the selection and timing of cultural practices to achieve the maximum mortality of overwintering pink bollworm larvae.

Methods and Materials

A study was conducted at Las Cruces, New Mexico, during the fall, winter, and spring of 1968-69 to examine the effects of irrigation, depth, and date of burial on mortality of overwintering larvae. Treatments were arranged in a 3 X 3 X 4 X 2 factorial with four replications in a split-split-split-plot design. The main and sub-plot treatments were three depths of burial, three irrigations, four dates of burial, and time of emergence--suicidal (on or before June 7) or non-suicidal (after June 7). The role temperature plays in determining the effectiveness of a single or a combination of cultural treatments was also studied.

Plots were artificially infested on November 25, 1968, with 7.7 kg of cotton bolls. Each 7.7 kg sample contained approximately 400 bolls. Four 7.7 kg boll samples were examined and found to contain 863 $\pm$ 23 larvae. Since each plot was replicated four times, a total of 3,452 $\pm$ 92 larvae were available for each treatment.

Burial of the bolls on December 4, 1968, and January 2, February 1, and March 4, 1969 was accomplished by removing the bolls and trash from the surface and digging the proper depth hole with a tractor scraper blade. The bolls and trash were scattered evenly in the hole and covered. In the stratified treatment, where burial was from 0 to 18 cm, one-seventh of the bolls by weight were alternated with approximately 2.5 cm of soil until one-seventh of the bolls remained on the soil surface. The one 10 cm irrigation was applied on March 7, and the two 10 cm irrigations were applied on January 4 and March 7.

Treatment effects were measured by placing emergence cages modified from Ellington et al. (1968) over the plots in March. The 14 cm square of sheet metal at the top of the cage was replaced with a cone-shaped piece. A quart jar lid was inverted and soldered to the cone. Quart fruit jars coated inside with Stikem^{R} were placed on the cage tops of all treatments to trap emerging moths. Trapped moths were recovered from the jar three times weekly. Cages were checked for three weeks after the last moth emerged on August 4.

Air and soil temperatures were recorded with no replications. Air temperature was taken from a recording hydrothermograph in a standard instrument shelter near the plots. Soil temperatures were monitored by a Foxboro 12-point recorder on the surface and at 8 and 15 cm in plots receiving zero, one, and two irrigations. The probe on the soil surface was covered with 5 mm of soil. Hourly temperatures from these eight locations were punched on IBM cards from which degree hr of cold could be computed for temperatures below 13.3° C.

Soil moisture percentages were determined from by-weekly soil samples taken from irrigated and non-irrigated plots at 8 and 15 cm, and a composite sample from 0 to 15 cm. Field capacity was determined from soil samples taken from the top 15 cm 24 hr after an irrigation. The hydroscopic soil moisture was determined as described by Kohnke (1968).

Results and Discussion

Moth emergence in the treatments is shown in Table VII (Appendix A) as those emerging suicidally on or before June 7 and non-suicidally after June 7. Because of the zero entries in the data, a transformation of $\sqrt{x + .5}$, where x is the number emerging, was applied before the data were analyzed. Based on an analysis of variance, all main and sub-plot treatment effects were significant at the .01 level of probability (Table VIII). Significant interactions effects were depth of burial by date of burial, depth of burial by time of emergence, and date of burial by time of emergence.

Single factor means were ranked and compared using Duncan's multiple range test (Table IX). Only the irrigation treatment effects are discussed since interactions existed among the other treatment effects. The means other than from the irrigation treatments are presented for informational purposes.

Differences in moth emergence between no irrigation and one spring irrigation were demonstrated in this study (Table IX). Lower moth emergence occurred from the plots receiving no irrigation. A winter plus a spring irrigation gave intermediate survival but was not significantly different from a zero or one irrigation. After mid-February, soil moisture in the upper 0 to 10 cm of the non-irrigated plots was below the one-half field capacity of 14.9%. Prior to and during peak moth emergence in May and early June, the soil moisture in the non-irrigated plots decreased to 5.5%, which is well below the 9% hydroscopic moisture level of the soil used in this study. The soil humidity is below 98% at the hydroscopic soil moisture level, indicating larval mortality probably occurred in the upper 0 to 10 cm of soil due to dessication and lack of moisture to stimulate pupation during April, May, and June. Except for two weeks in February, the plots irrigated once did not fall below one-half field capacity until the first week in May. Soil moisture in the plots irrigated twice was 3 to 8% above the soil moisture in the plots irrigated once and did not fall below one-half field capacity until the first week in May. The irrigated plots had sufficient moisture for pupation until late June, after which few moths emerged in any treatment. During the time cultural treatments were being applied, mean soil temperatures at 8 and 15 cm in the three irrigation treatments did not vary more than 1.1° C (Table X), nor did the soil temperature drop below -1.1° C; therefore, temperature was not considered a factor in the differences among the three irrigation treatments.

The magnitude of the effects due to the time of emergence, depth, and date of burial effects, and the presence of meaningful two-factor interactions of these treatments, necessitated examining trends of the three-factor treatment means (Table XI) before discussing the two-factor interactions. Burial at any depth on January 2 and burial at 15 to 18 cm on any date tended to have less non-suicidal emergence. A December 4 burial at 0 to 18 cm and 5 to 8 cm produced the most non-suicidal moth emergence. The three-way table revealed nothing that was not apparent in the two-factor interactions.

A lower survival of moths generally occurred due to deeper burial and burial on January 2. No significant differences existed in moth emergence from the 15 to 18 cm burial regardless of the date of burial (Figure 5, Appendix B). A 0 to 18 cm and a 5 to 8 cm burial on January 2 resulted in significantly lower survival than burial at these depths on any other date. Burial on December 4 at 0 to 18 cm increased survival over burial on any other date. A December 4 and February 1 burial at 5 to 8 cm produced less mortality of overwintering pink bollworms than burial on other dates. Shallow burial on December 4 appeared to protect the larvae. In January, the air and soil surface temperature averaged 3.6 and 2.7° C, respectively, greater than the December air and soil surface temperature means (Table X). Bolls exposed on the soil surface and then buried on January 2 were subjected to the cold temperatures occurring in December. Degree hours summation of air and soil surface temperatures at 2.8° C intervals revealed that December was colder than all other months (Table XII). Temperature on the soil surface where bolls were exposed prior to burial was colder than the air temperature. Chapman et al. (1960) indicated that larval mortality increased with the amount of time spent below 4.4° C. In December of the present study, the number of degree hours of air and soil surface temperatures below 4.4° C was about twice that of the next coldest month. The ratios between the number of degree hours of air and soil temperatures in December and January were greater at the temperature intervals below 4.4° C. Apparently, pink bollworm larvae are in a weakened condition after three or four weeks of cold temperatures and more susceptible to burial effects. Burying larvae on January 2 after the colder temperatures had occurred resulted in the greatest mortality to overwintering larvae.

A greater number of moths emerged suicidally than non-suicidally from all depths of burial (Figure 6) and from all dates of burial (Figure 7). Deeper burial and burial after December reduced non-suicidal moth emergence. Burial 0 to 18 cm and 5 to 8 cm on December 4 had significantly higher non-suicidal moth emergence, indicating that early shallow burial of overwintering pink bollworm larvae before cold temperatures occur should not be practiced. These data indicate that treatments which reduced emergence also resulted in a larger suicidal moth emergence. Increasing suicidal emergence would reduce the probability of the pink bollworm becoming a serious pest of cotton in New Mexico.

When water is available, plowing should be followed by one or more irrigations where a large infestation of pink bollworms has occurred, or a spring crop such as onions, lettuce, or barley should be grown to increase mortality of overwintering larvae.

A deeper burial of 15 to 18 cm on any date tended to produce the greatest mortality of overwintering larvae (Figure 5). Cotton fields should be plowed in such a manner as to bury overwintering pink bollworm larvae consistently as deep as possible. The inability to bury larvae consistently at 15 to 18 cm with a plow and the practice of disking cotton fields makes the date of burial important. January 2 as a burial date produced the greatest mortality, even in the 5 to 8 cm and 0 to 18 cm burials. To maximize winter mortality, plowing should be delayed until after cold weather has occurred.

CHAPTER V

CAGE SIZE AS RELATED TO CATCH OF PINK BOLLWORM MOTHS EMERGING FROM OVERWINTERING SITES

Various designs of emergence cages have been used in studies of the effects of cultural practices on overwintering survival of pink bollworm larvae. Fenton and Owen (1931) used a cage constructed of a wooden frame (.91 m^2) covered with a removable flat screen-wire top. The top was replaced in the spring with a piece of black sateen cloth having a small moth trap installed in the center. Shiller (1946) found that this cage stimulated premature moth emergence and moth trapping efficiency was low. He designed a more efficient cage of the same base size, fitted with a removable pyramid-shaped top covered with screen wire. A larger base size of 2 m^2 was used in Arizona by Watson and Larsen (1968). Watson's cage was collapsible but heavier and more burdensome. Ellington et al. (1968) developed a collapsible 2 m^2 pyramid-shaped cage that was lightweight, sturdy, inexpensive, and essentially weatherproof. The cage consisted of a 1.9-cm electrical conduit frame covered with fiberglass screen.

The present investigator used the Ellington cage in a study to evaluate the effects of cultural treatments on overwintering pink bollworm larvae during 1968 and 1969 at New Mexico State University. Moth catches in the Ellington cage from these cultural treatments were smaller than expected and less than catches in the Shiller cage in a similar study at the Texas Agricultural Experiment Station, El Paso (Travis L. Pate, unpublished data). Infested bolls picked at the same time and place were used in both of these studies. Cage size was believed to influence the number of moths caught from cultural treatments.

Based on observations from the 1968-69 experiments, studies were conducted in 1969 and 1970 to test the supposition that different cage sizes varied in trapping efficiency.

Methods and Materials

In the release-recapture study conducted in 1969, a randomized complete block design with 11 replications was used with three cage sizes and sex of moth as treatments. Dates of release were considered as replications. The trapping efficiency as related to moth sex was studied to detect a possible difference in male and female flight activity.

Two each of the Shiller cage (.91 m^2), Ellington conduit cage (2 m^2), and modified Ellington conduit cage (2 m^2) were used. The Ellington conduit cage was modified by reducing the angle of the four pyramid sizes, thereby lowering the height of the trap jar from 132 to 90 cm. The modified conduit cage had less volume, but was of the same base size as the Ellington cage. The modification allowed a comparison of the Ellington cage at two heights and two volumes. The trap jars on the modified Ellington and Shiller cages were the same height from the ground. Trap jars were coated internally with Stikem^{R} and placed on all cages to recapture the moths.

Pupae were sexed according to the characteristics described by Butt and Canter (1962) and were placed in separate emergence containers made from 3.8-liter plastic ice cream cartons. On the release day, the emergence containers were placed at 7.2° C until the moths became inactive. Moths less than three days old were used. Ten male moths were placed in each of three small baby food jars and ten females were placed in each of another set of three jars. Just prior to sunset, male moths were placed under one set of the three cage sizes and females under another set and released. Moths that left the release jars were counted as released. Recaptured moths were removed from the trap jars daily. No moths were recaptured in the trap jars after four days. Eleven releases were made from July 29 to October 27.

A second study was conducted during 1969-70 at El Paso, Texas, in cooperation with the Texas Agricultural Experiment Station, to compare the efficiency of the Shiller cage (.91 m^2) with the Ellington cage (2 m^2) in catching pink bollworm moths emerging from overwintering in plots receiving various cultural treatments. The treatments were arranged in a 2^3 factorial in a randomized complete block design with four replications. The treatments were cage sizes of .91 and 2 m^2, depths of burial of 5 and 15 cm, and zero or one irrigation. The bolls were buried on December 1, 1969, and the irrigated plots were irrigated with 15 ha cm of water on March 28, 1970. Moth emergence in the cages was recorded during the summer of 1970.

Results and Discussion

Data from the first study were recorded as percentage recaptured. Because of the zero responses, a transformation, arcsin (x + 1), was used where x equals the percentage recaptured (Table XIII, Appendix A).

The Shiller cage consistently captured moths of both sexes, but the Ellington and modified Ellington cages failed to capture moths 21 times out of 44 possible. The smaller cage captured 13 and 16% more moths than the Ellington and modified Ellington cages. The Shiller cage continued to capture moths during the colder nights of late August, September, and early October, while catches in the two larger cages were zero two-thirds of the times.

Size of cage and release dates were significant (P = .01) based on an analysis of variance (Table XIV). No difference existed in the percentage catch of male and female moths. The drop in the number of moths recaptured during September and October would be expected due to reduced moth activity during cooler nights. The effect of this reduced moth activity on percentage recaptured was particularly noticeable in the Ellington and modified Ellington cages (Table XIII). The means for the size of cages were compared using Duncan's multiple range test (P = .01). The Shiller cage (.91 m^2) caught significantly more moths than the Ellington or modified Ellington cages (2 m^2). No differences existed in recapture percentages between the Ellington and modified Ellington cages (Table XIII). Modifying the profile of the Ellington conduit cage to decrease its volume and lower the height of the trap jar did not significantly increase its moth trapping efficiency over the unmodified Ellington cage.

Moth emergence from cultural treatments applied to overwintering pink bollworm larvae in 1969 and 1970 was 7.4 times greater when measured by a Shiller cage as opposed to an Ellington cage (Table XV). The ratios of the number of moths caught by the two cage sizes were greater where larger numbers emerged from cultural treatments and were less where fewer numbers emerged. Because the great differences in the treatment responses resulted in heterogeneous variances, a Friedman rank test was applied to these data (Table XVI). Significant differences at the .01 level existed due to treatments. Shiller cages placed over a 5 cm burial with zero and one irrigations consistently captured the most moths. The three lowest ranking treatments had the Ellington cage installed over the plots. These data indicated that the same results cannot be expected where the Ellington cage (2 m^2) and Shiller cage (.91 m^2) are used to trap moths emerging from identical treatments.

Data from the second study (Table XV) were divided according to cages. A Friedman rank test was run on these two separate sets of data (Table XVII). Significant differences were detected in the treatments using a Shiller cage to trap emerging moths, but no treatment differences were found when the Ellington conduit cage was used. The Shiller cage gave consistent results except in one reversal in one replication, but the ranking of the responses from the Ellington cage seemed random (Table XVII).

In these studies, the Shiller cage (.91 m^2) was more efficient in recapturing moths than the Ellington or modified Ellington cages (2 m^2). Reducing the volume and trap jar height of the Ellington conduit cage did not increase its effectiveness over an unmodified cage. The Shiller cage gave better resolution of cultural treatment differences than the Ellington cage. These data indicate that a smaller cage of the design by Shiller (1946) should be used in place of a larger size such as designed by Ellington et al. (1968) for evaluating cultural treatment effects on the pink bollworm.

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APPENDIX A

TABLES

TABLE I

COMPARISON OF THREE INSECTICIDES APPLIED ULV FOR CONTROL OF THE PINK BOLLWORM

Treatments	Application rate kg AI/ha	Mean % of bolls infested* Sept. 11	17	23	29	Oct. 5
azinphosmethyl LC	.84	11.7	20.0	20.2	20.7	14.3
Guthion M-E + methyl parathion	1.12	10.2	21.5	17.0	16.7	12.1
Guthion M-E + methyl parathion	1.40	11.2	20.7	21.5	12.5	10.5
Co-Thion	1.40	9.2	14.2	16.2	13.5	9.8
Untreated check	0.0	10.0	15.0	17.0	13.2	11.1

*Insecticide applications were made on September 12, 18, 24, and 30, 1968.

TABLE II

ANALYSIS OF VARIANCE FOR INSECTICIDE TREATMENTS USING PRE-TREATMENT AND POST-TREATMENT INFESTATION COUNTS

Source	df	MS	F
Total	99		
Replications	3	365.77	11.32*
Treatments (A)	4	75.36	N.S.
Error a	12	32.31	
Dates (B)	4	274.62	13.92*
Error b	12	19.73	
A X B	16	14.15	N.S.
Error c	48	12.29	

*Significant at the .01 level.

TABLE III

ANALYSIS OF VARIANCE FOR INSECTICIDE TREATMENTS USING DIFFERENCES BETWEEN PRE-TREATMENT AND POST-TREATMENT INFESTATION COUNTS

Source	df	MS	F
Total	79		
Replications	3	7.04	N.S.
Treatments (A)	4	31.39	N.S.
Error a	12	68.87	
Dates (B)	3	209.91	8.12*
Error b	9	25.83	
A X B	12	16.78	N.S.
Error c	36	11.80	

*Significant at the .01 level.

TABLE IV

NUMBER OF PINK BOLLWORM MALES IN 1968 TAKEN IN STICKY TRAPS BAITED WITH A NATURAL SEX-LURE EXTRACT OF FEMALES

	Trap Heights (cm)				
Date	15 and 61		15	61	Totals
June 7	16	1	5	1	23
11	9	0	7	1	17
15	37	3	50	6	96
19	18	3	43	15	79
23	31	1	119	6	157
27	10	2	28	0	40
July 2	6	1	12	0	19
6	6	0	4	0	10
10	13	4	21	8	46
14	4	3	6	7	20
18	7	7	8	13	35
22	6	3	4	4	17
25	7	0	7	5	19
29	3	4	5	10	22
	173	32			
Treatment Totals	205		319	76	600

TABLE V

WEEKLY CATCH OF PINK BOLLWORM MALES IN 1969 IN HEXALURE-BAITED STICKY TRAPS PLACED IN COTTON

Hexalure per trap (mg)	5	5	10	10	10	10	20	20	
Trap height (cm)	91 and 15		91 and 15		91	15	91	15	Weekly Totals
Date									
May 19	0	2	0	6	0	6	1	13	28
26	0	4	1	10	1	8	2	17	43
June 2	0	5	1	12	1	8	2	20	49
9	1	8	1	17	2	14	3	24	70
16	2	17	2	17	3	20	7	35	103
23	2	8	5	12	2	10	5	16	60
30	3	5	6	9	3	6	7	13	52
July 7	2	1	4	3	2	2	6	5	25
14	3	1	5	1	3	2	5	3	23
21	1	0	4	2	3	1	7	2	20
28	6	2	9	2	7	1	13	3	43
Aug. 4	11	0	24	3	17	1	32	4	92
11	29	4	68	3	59	2	91	7	263
18	22	0	27	0	26	1	43	3	122
25	17	1	21	3	23	0	35	1	101
Sept. 1	15	0	31	1	21	1	39	2	110
	114	58	209	101					
Treatment Totals	172		310		173	83	298	168	1,204

TABLE VI

ANALYSIS OF VARIANCE FOR 1969 SEX LURE TRAPS SET AT 15 AND/OR 91 CM AND BAITED WITH 10 OR 20 MG OF HEXALURE PER LOCATION

Source	df	MS	F
Total	383		
Replications	3	5.44	
Treatments (A)	5	118.52	30.54*
Error a	15	3.88	
Weeks (B)	15	150.08	54.18*
Error b	45	2.77	
A X B	75	34.28	11.66*
Error c	225	2.94	

*Significant at the .01 level.

TABLE VII

PINK BOLLWORM MOTH EMERGENCE FROM SIMULATED CULTURAL TREATMENTS

Treatments			Moth Emergence		
Depth of burial (cm)	Number of 10 ha cm irrigations*	Dates of burial	Suicidal	Non-suicidal	Totals
5 to 8	0	Dec 4	32	5	37
		Jan 2	2	0	2
		Feb 1	12	1	13
		Mar 4	21	1	22
	1	Dec 4	57	15	72
		Jan 2	27	3	30
		Feb 1	45	5	50
		Mar 4	27	4	31
	2	Dec 4	37	5	42
		Jan 2	6	3	9
		Feb 1	28	9	37
		Mar 4	18	4	22
0 to 18	0	Dec 4	15	6	21
		Jan 2	7	1	8
		Feb 1	15	3	18
		Mar 4	13	4	17
	1	Dec 4	38	22	60
		Jan 2	7	4	11
		Feb 1	12	2	14
		Mar 4	20	6	26
	2	Dec 4	13	9	22
		Jan 2	3	2	5
		Feb 1	24	5	29
		Mar 4	17	1	18
15 to 18	0	Dec 4	0	0	0
		Jan 2	4	0	4
		Feb 1	5	0	5
		Mar 4	5	2	7
	1	Dec 4	9	0	9
		Jan 2	3	0	3
		Feb 1	14	2	16
		Mar 4	4	3	7
	2	Dec 4	1	0	1
		Jan 2	4	1	5
		Feb 1	10	4	14
		Mar 4	9	1	10
			564	133	697

*Plots receiving one irrigation were irrigated March 7, 1969, and plots receiving two irrigations were irrigated January 4 and March 4, 1969.

TABLE VIII

SPLIT PLOT ANALYSIS OF VARIANCE OF EFFECTS OF SIMULATED CULTURAL TREATMENTS ON OVER-WINTERING PINK BOLLWORM LARVAE

Source	df	MS	F
Total	287		
Replications (RE)	3	.48	
Depth of burial (A)	2	14.23	113.50*
Error a	6	.12	
Irrigations (B)	2	4.79	8.25*
AB	6	.75	1.30
Error b	18	.58	
Date of burial (C)	3	5.47	18.46*
AC	6	1.64	5.53*
BC	6	.98	2.90
ABC	12	.34	1.51
Error c	81	.30	
Time of emergence (D)	1	46.47	249.64*
AD	2	3.73	20.03
BD	2	.64	3.46
ABD	4	.32	1.73
CD	3	1.11	5.97*
ACD	6	.38	2.07
BCD	6	.17	.93
ABCD	12	.24	1.27
Error d	108	.19	

*Significant at the .01 level.

TABLE IX

MEAN NUMBER OF MOTHS EMERGING IN EACH OF THE FOUR TREATMENTS COMPARED USING DUNCAN'S MULTIPLE RANGE TEST*

Depth of burial (main treatment)

15 to 18 cm	0 to 18 cm	5 to 8 cm
1.07	1.61	1.81

Irrigations** (sub-plot treatment)

0	2	1
1.17	1.49	1.72

Date of burial (sub-sub-plot treatment)

Jan. 2, 1969	Mar. 4, 1969	Feb. 1, 1969	Dec. 4, 1968
1.12	1.48	1.61	1.77

Time of emergence (sub-sub-sub-plot treatment)

non-suicidal	suicidal
1.09	1.90

*Means connected by the same line are not significantly different at the .01 level.

**0 = no irrigation; 1 = irrigation on March 7; 2 = irrigations on January 4 and March 7, 1969.

TABLE X

MEAN MONTHLY HOURLY TEMPERATURES (° C)
OF EIGHT LOCATIONS

			Number of irrigations					
			0	1	2	0	1	2
			Depth of temperature probe in soil (cm)					
		Soil	8			15		
Date	Air	Surface						
Dec. 1968	3.0	3.1	4.3	4.6	4.4	4.2	4.8	4.1
Jan. 1969	7.2	6.4	7.0	7.1	6.1	7.1	7.1	6.6
Feb. 1969	6.9	7.9	8.5	8.4	7.8	8.4	8.5	8.3
Mar. 1969	8.5	11.1	10.3	9.0	8.5	9.9	8.0	9.0

TABLE XI

MEAN NUMBER OF PINK BOLLWORM MOTHS EMERGING SUICIDALLY AND
NON-SUICIDALLY IN THE DEPTH OF BURIAL AND
DATE OF BURIAL TREATMENTS

	Suicidal				Non-Suicidal			
Depth of burial	Date of Burial				Date of Burial			
(cm)	Dec. 4	Jan. 2	Feb. 1	Mar. 4	Dec. 4	Jan. 1	Feb. 1	Mar. 4
5- 8	3.18	1.16	2.60	2.31	1.50	.95	1.25	1.06
0- 8	2.34	1.13	2.13	2.08	1.78	1.00	1.11	1.09
15-18	1.59	1.10	1.38	1.10	.70	.75	.95	.93

TABLE XII

DEGREE HOURS SUMMATION AT 2.8 ° C INTERVALS OF AIR AND SOIL SURFACE TEMPERATURES BELOW 13.3° C FOR MONTHS DURING WHICH SIMULATED CULTURAL PRACTICES WERE APPLIED TO OVERWINTERING PINK BOLLWORM LARVAE

	-9.6	-6.8	-4.0	-1.2	1.6	4.4	7.2	10.0	<13.3
				Air Temperature (° C)					
Dec.	3	41	217	749	1,606	2,724	4,048	5,598	7,748
Jan.	0	1	51	233	580	1,168	2,075	3,277	5,004
Feb.	0	0	18	161	497	1,065	1,927	3,051	4,076
Mar.	0	0	7	106	412	955	1,792	2,915	4,606
				Soil Surface Temperature (° C)					
Dec.	9	104	493	1,249	2,266	3,529	4,945	6,497	8,487
Jan.	0	2	106	392	971	1,862	3,035	4,402	6,239
Feb.	0	3	60	306	832	1,619	3,628	3,800	5,356
Mar.	0	8	77	280	680	1,338	2,294	3,417	4,956

TABLE XIII

NUMBER OF MALE AND FEMALE PINK BOLLWORM MOTHS RECAPTURED IN THREE CAGE SIZES REPORTED AS THE TRANSFORMATION, ARCSIN (PERCENTAGE RECAPTURED + 1)

	Cage Type and Size and Sex of Moths Released					
Date of Release	Shiller (.91m^2) Male	Shiller (.91m^2) Female	Modified Ellington (2 m^2) Male	Modified Ellington (2 m^2) Female	Ellington (2 m^2) Male	Ellington (2 m^2) Female
July 29	33.46	60.67	5.74	23.58	50.65	5.74
Aug 2	61.96	50.13	51.35	45.57	41.03	48.45
6	34.33	47.47	45.57	42.36	21.56	32.96
11	19.37	33.83	19.37	19.37	19.37	19.37
15	5.74	28.79	5.74	5.74	20.36	5.74
21	19.37	23.03	5.74	5.74	5.74	5.74
26	60.67	45.57	30.66	35.67	5.74	5.74
Sept 4	27.28	33.83	5.74	27.28	20.36	5.74
19	38.35	27.28	5.74	5.74	5.74	27.28
23	27.28	19.37	33.83	39.82	33.83	5.74
Oct 7	39.82	20.36	5.74	5.74	5.74	5.74
Sex Means*	33.42	35.47	19.57	23.32	20.92	15.29
Size Means**	34.45a		21.45b		18.11b	

*Sex Means: Not significant according to analysis of variance in Table XIV.

**Size means followed by the same letter are significantly different at the .01 level as determined by Duncan's multiple range test.

TABLE XIV

ANALYSIS OF VARIANCE OF MALE AND FEMALE PINK BOLLWORM MOTHS RECAPTURED IN THREE CAGE SIZES

Source	df	MS	F
Total	65		
Replication (release dates)	10	836.94	6.29*
Size of trap (A)	2	1,640.76	12.34*
Sex of moth (B)	1	0.07	N.S.
A X B	2	137.63	N.S.
Error	50	132.92	

*Significant at the .01 level.

TABLE XV

PINK BOLLWORM MOTHS CAUGHT IN TWO CAGE SIZES PLACED OVER IDENTICAL CULTURAL TREATMENTS APPLIED IN 1969 AND 1970 TO OVERWINTERING LARVAE IN COTTON BOLLS

Type and size of cage	Depth of boll burial (cm)	Number of 15 ha cm irrigations	Replications 1	2	3	4	Treatment Totals
Ellington (2 m^2)	5	0	9	1	3	9	22
	5	1	15	13	5	17	50
	15	0	2	2	6	1	11
	15	1	19	2	0	4	25
							108
Shiller (.91 m^2)	5	0	50	56	24	27	157
	5	1	111	176	171	74	532
	15	0	15	20	12	12	59
	15	1	12	7	2	25	46
							794

TABLE XVI

RANKINGS* FOR TWO CAGE SIZES PLACED OVER IDENTICAL CULTURAL TREATMENTS AS MEASURED BY NUMBER OF EMERGING PINK BOLLWORMS CAUGHT IN CAGES

Cage type	Depth of boll burial (cm)	Number of irrigations	Rankings by Replications 1	2	3	4	Treatment** Rank Totals
Ellington	5	0	2	1	3	3	9
Ellington	15	0	1	2.5	5	1	9.5
Ellington	15	1	6	2.5	1	2	11.5
Shiller	15	1	3	4	2	6	15
Ellington	5	1	4.5	5	4	5	18.5
Shiller	15	0	4.5	6	6	4	20.5
Shiller	5	0	7	7	7	7	28
Shiller	5	1	8	8	8	8	32

*Lower ranking numbers indicate lower moth catch.

**Treatment effects were significantly different at the .01 level according to the Freidman rank test.

TABLE XVII

COMPARISON OF THE RELATIVE ABILITY OF TWO CAGE SIZES TO MEASURE CONSISTENTLY EFFECTS OF IDENTICAL CULTURAL TREATMENTS ON OVERWINTERING PINK BOLLWORM LARVAE

Type and size of cage	Depth of burial (cm)	Number of irrigations	Rankings* within cage size by Replications				Treatment Rank Totals
			1	2	3	4	
Shiller**	15	1	1	1	1	2	5
	15	0	2	2	2	1	7
	5	0	3	3	3	3	12
	5	1	4	4	4	4	16
Ellington***	5	0	2	1	2	3	8
	15	0	1	2.5	4	1	8.5
	15	1	4	2.5	1	2	9.5
	5	1	3	4	3	4	14

*Lower number indicates lower moth catch.

**Significant differences found at the .05 level between treatment effects evaluated by this cage as determined by the Friedman rank test.

***No significant differences found at the .05 level between treatment effects evaluated by this cage as determined by the Friedman rank test.

APPENDIX B

FIGURES

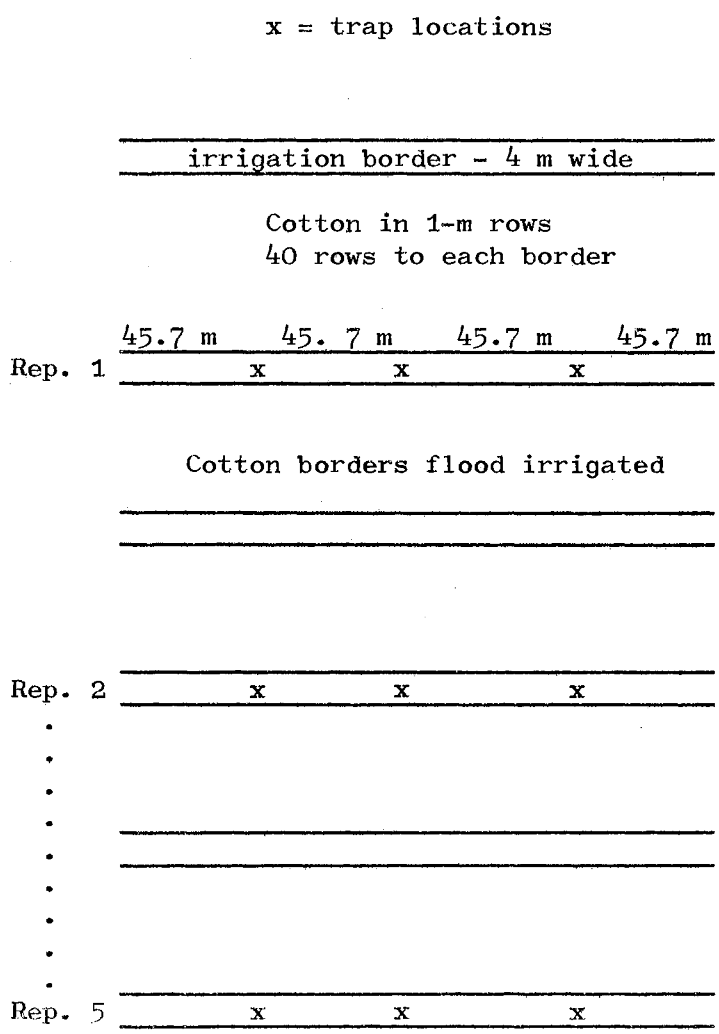

Figure 1. Diagram of Field Layout of 1968 Sex Lure Study Using Sticky Traps Baited With Natural Sex Lure Extract of Female Pink Bollworms

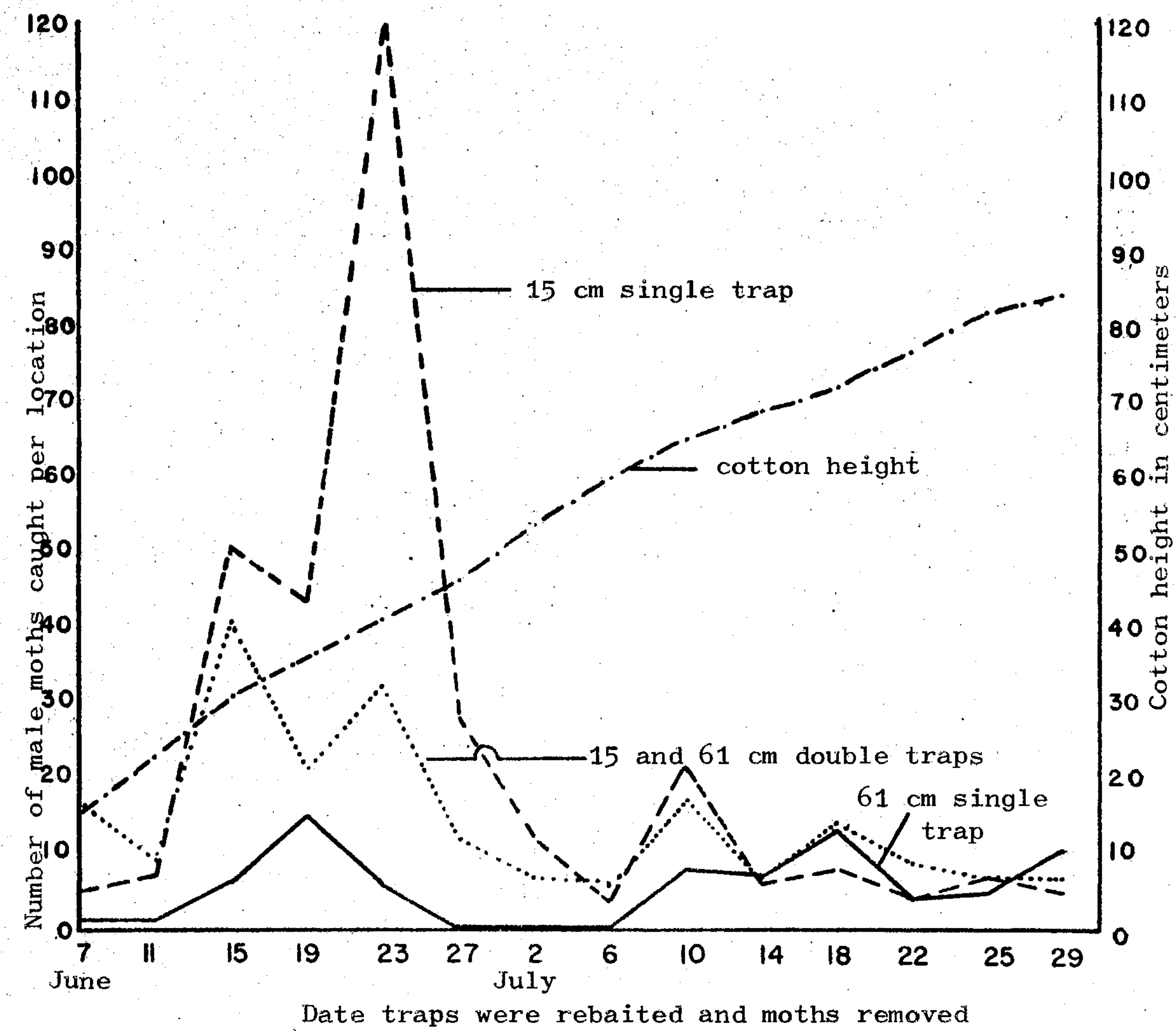

Figure 2. Number of Male Pink Bollworms Caught in Sex-Lure-Baited Sticky Traps and Cotton Growth Curve During 1968

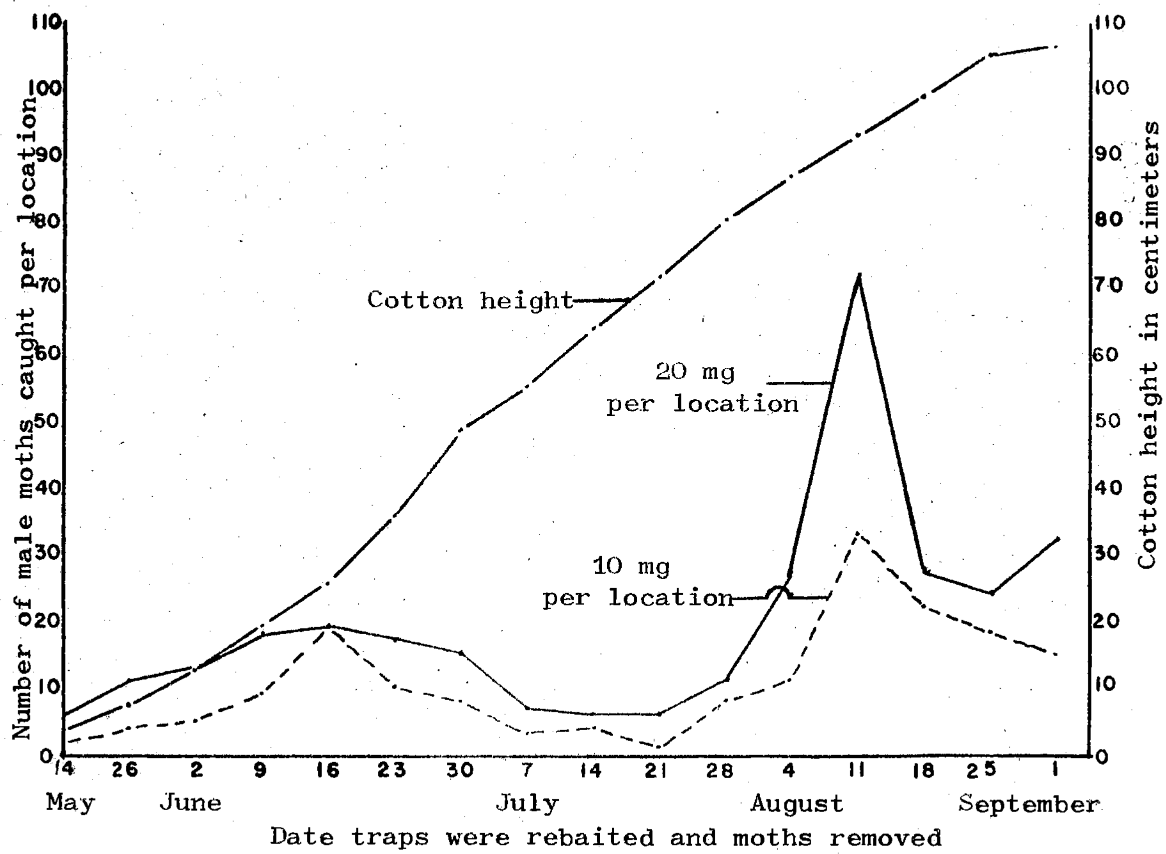

Figure 3. Number of Male Pink Bollworms Caught in 1969 in Sticky Traps Set Two Per Location at 15 and 91 CM above the Ground in Cotton and Baited With 5 or 10 MG of Hexalure Per Trap in 1969

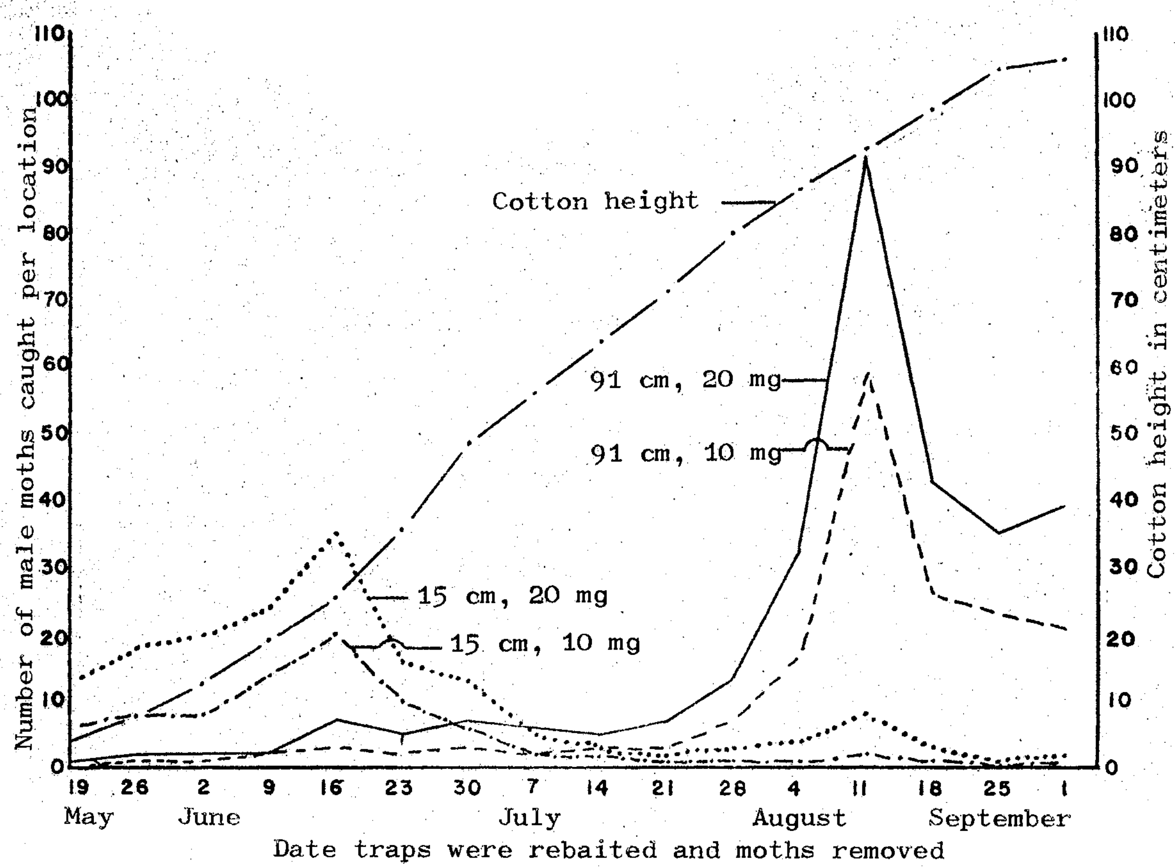

Figure 4. Number of Male Pink Bollworms Caught in 1969 in Sticky Traps Set One Per Location at 15 or 91 cm above the Ground and Baited With 10 or 20 mg of Hexalure Per Trap

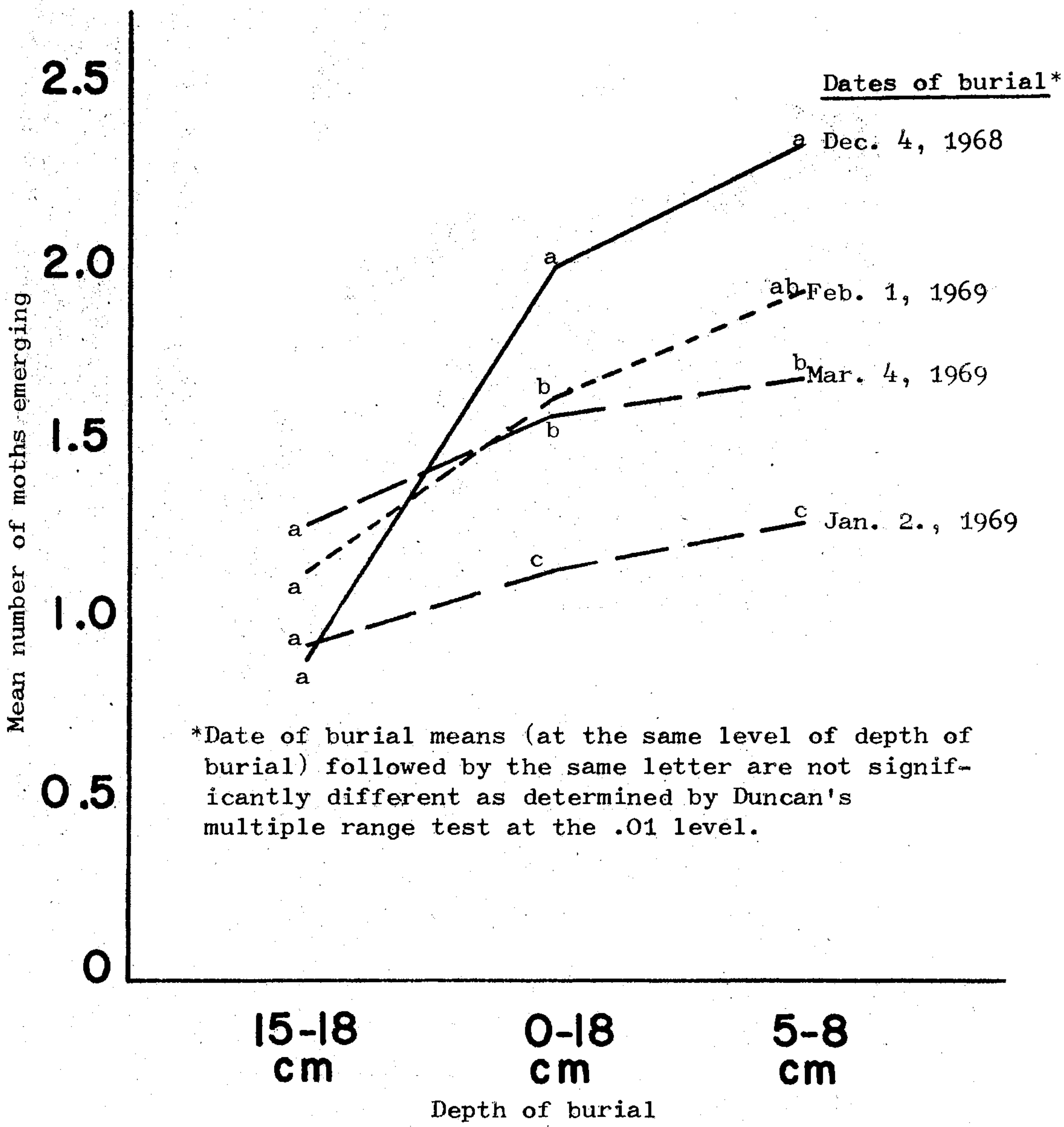

Figure 5. Mean Number of Moths Emerging From the Depth and Date of Burial Treatments

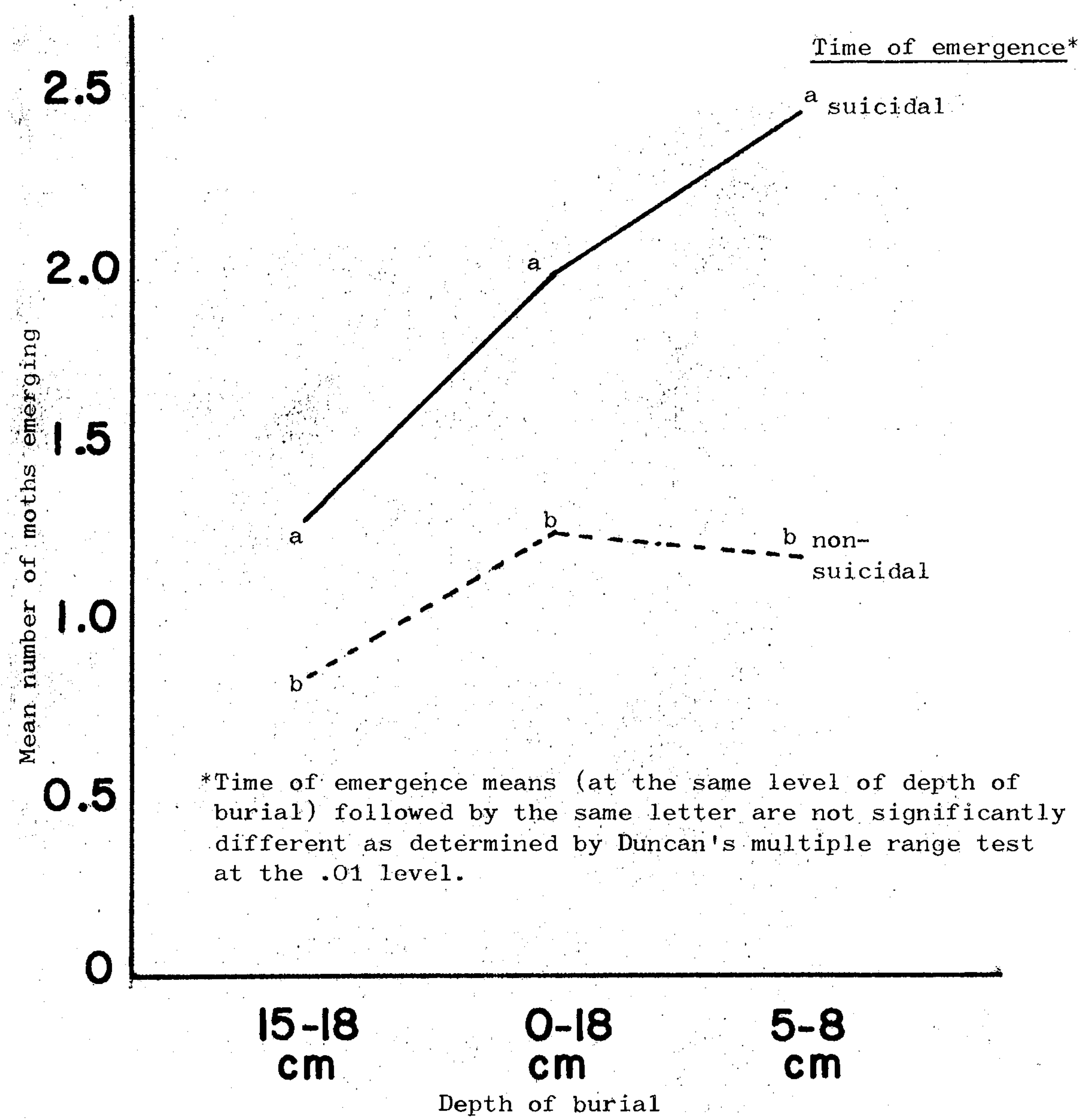

Figure 6. Mean Number of Moths Emerging Suicidally or Non-Suicidally From the Depth of Burial Treatments

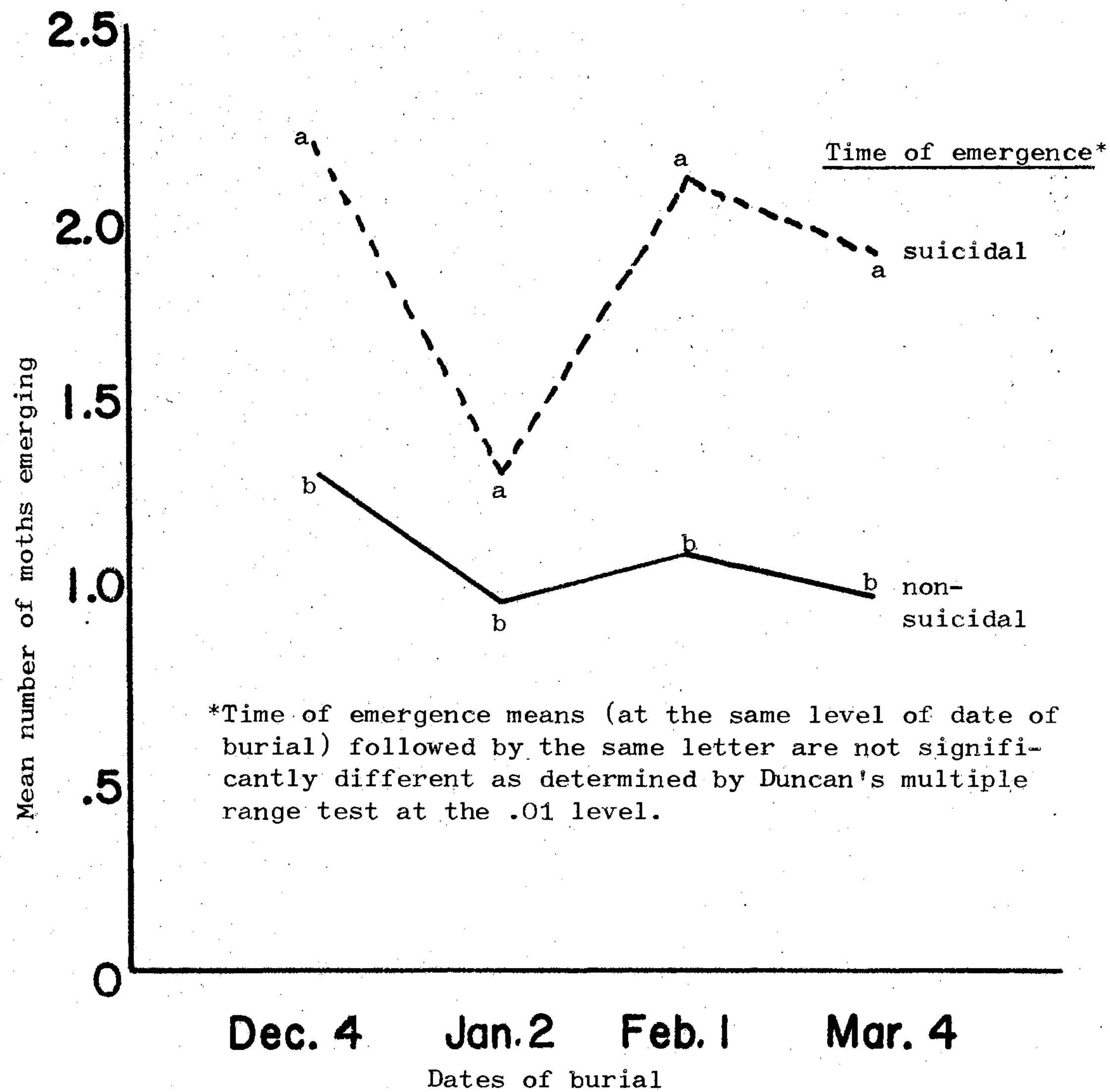

Figure 7. Mean Number of Moths Emerging Suicidally or Non-Suicidally From the Date of Burial Treatments

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