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POPULATION DYNAMICS OF THE BOLL WEEVIL AND MODIFIED COTTON TYPES

Implications for Pest Management

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SUMMARY

The population dynamics of the boll weevil in cotton was investigated near College Station from 1960 to 1963 and from 1965 to 1968. Findings showed that the time of weevil generations in cotton was predictable. Rates of increase of first generation insects from small numbers of overwintered weevils were as great as thirtyfold. When large populations of the overwintered pests infested cotton, a reduction in reproductive efficiency occurred. Rates of increase of twofold to fivefold were recorded. Economic threshold data showed that overwintered populations must be reduced to about 22 females per acre in order not to experience damage from the first generation. Forty or more overwintered females per acre produced ample first generation weevils to inflict heavy damage. When Lankart Sel. 57 cotton was used, it was apparent that the major threat of boll weevil damage would result from the first generation. That is, if cotton escaped damage from this generation, the crop would be too mature to experience damage from the second generation, regardless of the size of the second generation. Concepts gained from this study dramatize the importance of early maturing cottons in escaping boll weevil damage and in reducing winter carryover of diapausing individuals. Certain new experimental strains of cotton, when planted in high density culture, seem to escape weevil damage and reduce winter carryover.

POPULATION DYNAMICS OF THE BOLL WEEVIL AND MODIFIED COTTON TYPES

Implications for Pest Management

*J. K. Walker, Jr. and G. A. Niles**

Few insects in the United States have created an economic impact equal to that which resulted from the depredations of the boll weevil, *Anthonomus grandis* Boheman, as the pest moved across the rainbelt cotton-producing area of the United States in the early 1900's. Within a few years, common production methods became impractical; and, at least for a while, alternatives were slow to develop. Before the boll weevil invasion, growers farmed cotton in an agro-eco system that did not contain a single pest that had the potential of the weevil for yearly repetitive damage. There were outbreaks of bollworms, *Heliothis zea* Boddie, especially in Texas and Oklahoma, and cotton leafworms, *Alabama argillacea* (Hubner), were not uncommon. But because of various biological and ecological reasons, these insects were not widespread universal pests of cotton.

The boll weevil was not subjected to the environmental limitations imposed on the bollworm and cotton leafworm. The weevil is essentially a one-host insect that remains on cotton during the entire growing season. From moderate numbers of overwintered parents, the pest may develop into yield-damaging populations within the span of a single generation. Predation and parasitism by other arthropods do not effectively control the boll weevil. Also, in nearly all the areas where the pest infests cotton during the summer, the weevil can overwinter. Any insect species possessing these attributes has the potential of being a dangerous economic pest. The boll weevil, of course, has proven to be one of the most destructive pests ever introduced into the United States.

The commercial cotton varieties grown before the boll weevil era were slow to fruit and, consequently, were especially vulnerable to the insect. It became apparent to researchers that earliness in cotton varieties was the most effective and immediate way to reduce damage from the weevil (1). It became clear that if cotton were to continue being grown profitably, as much production as possible must be made early in the growing season before weevil populations developed into great numbers. Breeders at a number of locations initiated programs to select cottons that possessed early fruiting characteristics. These efforts were successful; early varieties were developed, and growers incorporated them into their production programs. Cotton production in the rainbelt area survived (2). For all practical purposes, the substitution of early producing cottons was the only means used by growers that allowed farmers to produce cotton successfully in spite of the weevil. An effective insecticide was found in calcium arsenate dust in 1918, but for various reasons many planters did not use the material (3).

In addition to the use of early fruiting plant types to lessen weevil damage, early entomologists recognized that cotton plants should be destroyed as soon as possible after harvest in the fall (4). These scientists were aware that something was different about many of the boll weevils in the fall generations, and somehow this difference allowed the insects to overwinter successfully (5). Today it is known that the overwintering ability of the boll weevil is due to diapause, a physiological adaptation occurring primarily in the fall that permits the insect to overwinter in cold climates (6).

Stalk destruction immediately after harvest was thought to lessen the overwintering potential of boll weevil populations as a result of the removal of cotton as a food source. In a period of time when cotton was harvested by hand over a period of several months, it is doubtful that stalk destruction could ever have been carried out early enough in the season to produce a great reduction in potential overwintering weevil population. Nevertheless, the concept was sound, and in recent years it has been amplified in the fall control of diapausing boll weevils on the High Plains of Texas (7). In this program organophosphate insecticides have been directed toward boll weevils that have the potential for diapause. In effect, this accomplishes the same goal as the old recommendation for early stalk destruction.

Despite the benefits that might have resulted from stalk destruction practices in the first years after the boll weevil invaded the United States, there was abundant winter survival of the pest. Infestation intensity varied with the season and location. The

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early fruiting cottons allowed growers to continue production, but the effective production period was limited in general to the first few weeks of fruiting. After that time boll weevil populations often would explode into great numbers and eliminate further fruit set by the crop. Consequently, the high yields produced by present production methods were impossible.

This situation continued until the appearance of the chlorinated hydrocarbon insecticides in the first years after World War II. These broad spectrum compounds were dramatically effective and at the time appeared to offer great promise for insect-free cotton production. Control was spectacular, and yields greatly increased. It became profitable to grow indeterminate cotton varieties that continued to fruit throughout the growing season. Successful insect control fostered irrigation and fertilizer practices, thus increasing the demand for longer fruiting and high-yielding relatively indeterminate varieties of cotton. Production hinged on the duration of the growing season in an area, not on how much time the crop had to set fruit before boll weevils attained large populations.

The prolonged fruiting patterns of the indeterminate cottons, although increasing yield potential, served to provide ample food for weevils developing diapause in the fall after insecticidal treatments had been halted. This situation ran counter to the old stalk destruction concept; however, this actually made little difference. The boll weevil could be controlled easily with the new insecticides during the growing season despite the survival of great numbers during the winter.

It became apparent to many entomologists, and later was shown experimentally, that applications of the broad-spectrum organic insecticides directed toward the boll weevil resulted in almost total destruction of the beneficial arthropod population in cotton (8, 9). This unfortunate result eliminated insect predation and parasitism and led to outbreaks of the bollworm-tobacco budworm complex in the cotton field. The damage inflicted by these pests often equals that of the boll weevil's presence which initiated the insecticidal treatment.

The boll weevil came to be known as a "key" insect. That is, control programs had to be initiated for the weevil; but following the first insecticidal treatments, secondary pests, that is, the bollworm and tobacco budworm, often would increase because of the decimation of the beneficial arthropods that normally control them. However, the bollworm-tobacco budworm did not present a serious problem to producers for many years because these insects could be effectively and economically controlled with DDT.

In summary, the new organic insecticides were so effective that earliness of production and prompt stalk destruction were no longer considered essential to boll weevil control. Most phases of research related to cotton production, entomological and otherwise, came to be based on the pomise of effective and continued insecticidal pest control. There was little concern that the certain insects had developed resistance to DDT a few years after the insecticide was first used in the 1940's.

By the mid-1950's, the long term credibility of insecticides came under close scrutiny as the boll weevil developed resistance to certain chlorinated hydrocarbon insecticides in Louisiana (10). In the next few years most of the rainbelt cotton producing states experienced the same problem, and in the 1960's chlorinated hydrocarbon resistance began to appear in bollworm-tobacco budworm populations (11). Growers solved the chlorinated hydrocarbon-resistance problem by switching to organo-phosphate insecticides. Recently, however, high levels of resistance to the organo-phosphate insecticides have been detected in field populations of the tobacco budworm and in laboratory cultures of the bollworm (12, 13). As growers continue to treat with organo-phosphate materials, these two pests will develop even greater levels of resistance.

The implications for the future are clear. Cotton insects will have to be controlled or managed with techniques that place less emphasis on the use of insecticides. There are no alternate insecticides available for use, and there is small likelihood of new ones being developed in the near future. Alternate methods for solving cotton insect pest problems will have to be devised if the crop is to be profitably grown in the rainbelt area.

New approaches to cotton insect control probably will be built around the pest management concept. The aim of this method is to use a combination of techniques that collectively hold a pest species below the economic threshold of damage while at the same time produce a minimum of deleterious side effects in the agro-eco system. Eradication or high levels of control are not sought in pest management; instead, the goal is economic containment of the pest.

The diapause boll weevil control program that has been successfully followed on the Texas High and Rollings Plains may be considered a method of pest management. Three practices conducted in this program combine to reduce the winter carryover of boll weevils. These are 1) insecticidal control of the last reproductive generation of weevils; 2) insecticidal control to kill potential diapausing weevils during the fall months; and 3) defoliation and stalk destruction to remove the cotton food source that is necessary for the development of overwintering weevils. Although insecticides are used in this program, the materials are applied after the production period is over and when the crop is no longer susceptible to damage by bollworm-tobacco budworm infestations.

Recent findings appear to offer new opportunities for the management of boll weevil populations. This study considers the population dynamics of the boll weevil and how these phenomena might relate to new highly determinate rapid-fruiting cottons.

Methods

Population Dynamics of the First Generation

The purpose of the study was to determine the rates of increases of first generation boll weevils in cotton infested with various numbers of overwintered weevils and to ascertain how the overwintered and first generations related to the phenology of the cotton plant. The experiments, during the 4-year period, 1960-63, were conducted in a 1/22-acre plot of cotton (6 rows × 100 feet) planted near Easterwood Airport at College Station, Texas. The site was in a small cleared creek bottom surrounded by dense woods, located about 2 miles from the Brazos River Valley where large acreages of cotton are grown. Beginning about June 1—just before squaring—the cotton in the plot was examined two to three times per week, and various data were obtained. Records were made of the numbers of overwintered boll weevils, square production and numbers of squares punctured.

Overwintered weevils were allowed to oviposit for 17 to 19 days after appearance of the first one-third grown squares (squares first acceptable for oviposition by female weevils). Subsequently, the insects were hand-removed, and an application of methyl parathion was made to kill any weevils that might have been overlooked, thereby, preventing further egg deposition by the overwintered brood. Any weevils found after this time were assumed to be of the first generation. In 1963 overwintered weevils were removed from the plot in such a manner that a population of 500 adults or less per acre could be maintained. During the season, first generation emergence data were noted in the plots at intervals of 1 or 2 days following the 17- to 19-day period of overwintered weevil infestation. First-generation sampling continued until about 45 days after squaring began. All weevils found were removed from the plot and destroyed.

Population Dynamics of the Second Generation

This experiment was conducted from 1965 to 1968 in the same location and plot as the previous experiment. The study was designed to measure the size of second generation populations of boll weevils which developed from varying numbers of overwintered weevils. Also, the relationships of the overwintered brood and the first and second generation to the phenology of the cotton plant were examined. The technique in this experiment differed from that used for the first generation study in that all overwintered weevils encountered in sampling were sexed and marked with small spots of lacquer on the elytra. This allowed re-identification and permitted careful assessment of the numbers of female weevils infesting the plot.

Since one of the objectives of the study was to measure the total number of second generation weevils produced, the application of methyl parathion was not made until the conclusion of first generation weevil emergence or about 39 to 44 days after the first one-third grown squares appeared on the cotton plants. Thus, the overwintered and first generation individuals were allowed to oviposit unmolested. Individuals emerging after 39 to 44 days of squaring were assumed to be members of the second generation; these were removed and destroyed.

Results

First Generation Studies

1960—The first one-third grown squares appeared June 10, and an extremely large number of overwintered weevils (Figure 1) punctured a great percentage of these and later forming squares (Figure 2). The population averaged 2,693 overwintered individuals per acre during the first 17 days of the squaring period. The total number (13,354 per acre) of first generation weevils represents about a five-fold rate of increase from the overwintered population (Figure 1).

1961—Again, large numbers of overwintered weevils (Figure 1) infested the plot and punctured a great percentage of the squares during the first 18 days of fruiting (Figure 1 and 2). The rate of increase of the first generation (6,050 weevils) over the average of the parent brood (2,728 weevils) was about twofold.

1962—The results differed markedly from the previous two seasons. From an average overwintered population of 314 per acre during the first 18 days of fruiting, a first generation of 10,274 individuals per acre developed (Figure 1). The rate of increase was about 33-fold. This large difference in rate of increase between 1962 and the first 2 years of the experiment is explained in Figure 2. The graphic representations of square production in 1960 and 1961 are relatively flat lines; this is unlike the normal fruiting sequence of cotton and contrasts sharply with the rapid rates of squaring recorded in 1962 and 1963. The feeding and oviposition activities of the enormous populations of 1960 and 1961 actually limited square production and consequently the number of oviposition sites. The occurrence of multiple feeding and egg punctures in individual squares, especially where the crowded weevils were forced on to very small squares, caused the fruits to be shed early, almost as rapidly as they appeared on the plant. This restricted the development of normal numbers of squares optimum in size for oviposition. The first generation weevils in 1960 and 1961 were the victims of the density of their parents. There was such competition for young squares for feeding by the parents that few suitable squares were left for oviposition and development of the larvae. Thus, a high density population has a built-in mechanism for controlling its numbers.

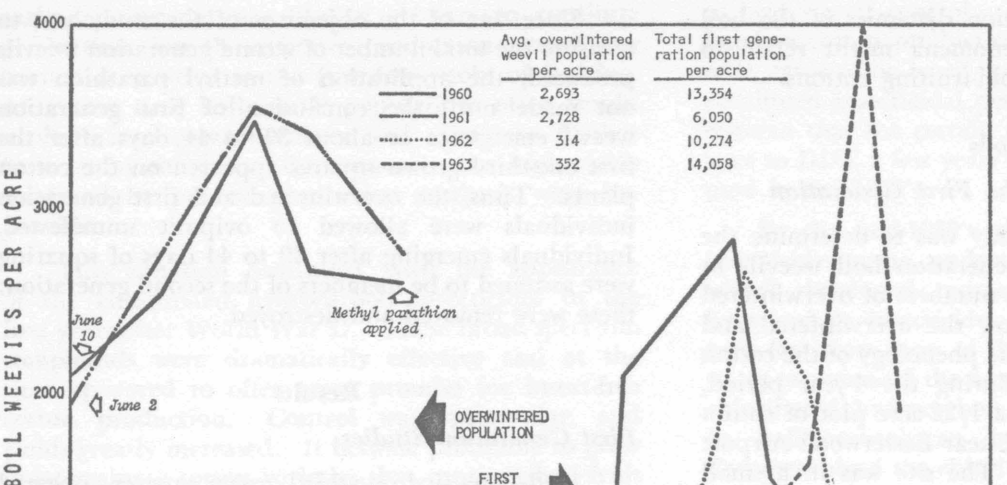

Figure 1. Development of first generation boll weevils from different populations of overwintered weevil parents in a 1/22-acre plot of cotton, 1960-63. The overwintered insects were allowed to oviposit in each of the years for about 20 days; then they were destroyed with methyl parathion. Weevils recorded after the application were first generation insects and were removed when counted.

It increases at a much lower rate than a low density population because of intro-specific competition.

1963—As in 1960 and 1961, large numbers of overwintered weevils infested the plot. In order to maintain a smaller weevil population, the cotton was examined three times a week during the first 19 days of fruiting, and sufficient overwintered weevils were hand-removed to maintain fewer than 500 individuals per acre. A total of 1,760 weevils per acre was removed. The remaining population averaged 352 per acre during the first 19 days of squaring (Figure 1).

The rate of increase of the F_1, first generation, population (14,058) over the average overwintered population (352) was fortyfold (Figure 1). However, it is likely that this rate was somewhat inflated since weevils were removed from the plot at frequent intervals to establish an average population of 352. Undoubtedly, the weevils which were removed had deposited some eggs; therefore, the oviposition which occurred probably was somewhat greater than would have been accomplished by an average population of 352 overwintered weevils.

The percentage of squares punctured by the overwintered weevils was greater than the year before (Figure 2), but apparently no interference with fruiting occurred. As in 1962, very rapid square production took place during the first 19 days of squaring, and the population of overwintered weevils should have had ample oviposition sites. As in 1962 these results strikingly contrast with the data obtained in 1960 and 1961. The concept of density dependence seems to have an important bearing on the natural rate of increase of the boll wevil. Reproductive efficiency is favored when cotton is infested by small numbers of overwintered weevils.

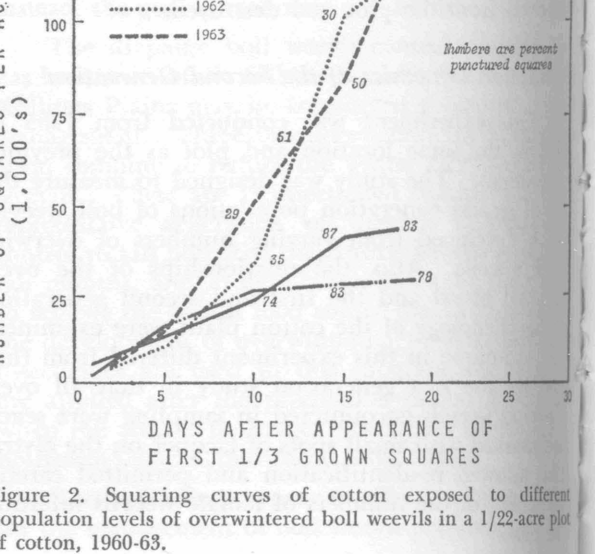

Figure 2. Squaring curves of cotton exposed to different population levels of overwintered boll weevils in a 1/22-acre plot of cotton, 1960-63.

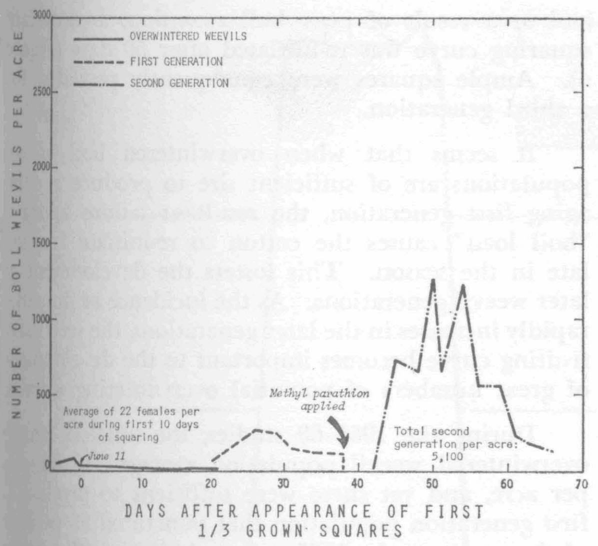

Figure 3. Development of boll weevil generations in a 1/22-acre plot of cotton, 1965. The overwintered and first generation insects were allowed to oviposit for 39 days; then the weevils were destroyed with methyl parathion. Weevils recorded after the application were second generation insects and were removed when counted.

The potential for tremendous population expansion by the weevil may be seen from these 4 years of study, and it is apparent that overwhelming numbers of progeny will result from several hundred overwintered boll weevils per acre. Where these levels of the overwintered brood occur, a grower would have an effective production period of about 30 days after the first one-third grown squares appeared. After that time the accumulation of several thousand first generation individuals per acre would drastically reduce further fruit set. Previous studies in the Central Texas area have shown that severe damage occurs in cotton when boll weevil numbers reach about 1,000 per acre (14).

Second Generation Studies

In the next several years, population studies were continued to measure the size of the second generation and its relationship to overwintered and first generation weevil numbers and to determine how these relate to the phenology of the cotton plant. The numbers of overwintered weevils naturally infesting the plot were considerably smaller than those encountered in the first generation studies. This was fortunate as it allowed a critical examination of numbers of the second generation individuals that might result from relatively small numbers in the overwintered generation.

1965—The overwintered female boll weevil population infesting the plot was equivalent to 22 females per acre (Figure 3). These occurred during the first 10 days after one-third grown squares first appeared. Overwintered females were not found in the plot after this time. From this infestation of 22 females, which oviposited during the first 10 days of squaring, a peak number of approximately 300 first generation weevils per acre were counted. The overwintered male and female population combined generally punctured less than 1 percent (Figure 4) of the squares during the first 18 days of squaring. The percentage of squares punctured by first generation weevils gradually increased, and by 40 days after squaring, 18 percent were punctured. This population level of first generation weevils was well below the economic threshold.

Second generation weevil emergence began 45 days after the first eggs of the season were laid in the first one-third grown squares (Figure 3). A total population of 5,100 individuals per acre was recorded. These resulted from an initial population of only 22 overwintered females per acre.

Figures 5 and 6 show how the squaring and flowering curve for 1965 might be partitioned into those portions exposed to each of the generations. Under the present study conditions, the greatest threat to cotton production would be realized from the first generation of boll weevils. The second generation, although large, began emergence at a time when there was a rapid cessation of fruiting as the crop neared maturity. Consequently, the damage potential of the second generation appears to have been small. This premise is supported by results of studies conducted in North Carolina to determine the length of time that applications of insecticides for boll weevils should continue with respect to the squaring curve of cotton

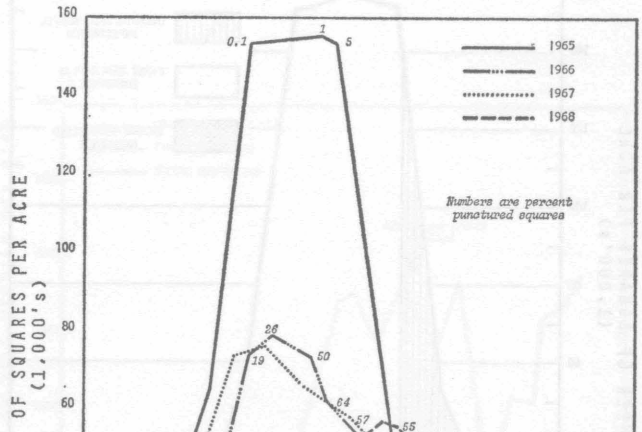

Figure 4. Seasonal squaring curves in a 1/22-acre plot of cotton exposed to different population levels of boll weevils, 1965-68.

(15). Results of this research indicated that increased production was not obtained by continuing applications past the time that cotton squaring had diminished to about 13,000 squares per acre (one square per row foot). Figure 4 indicates that the second generation weevils in the present study did not start emerging until squaring had decreased to about 13,000 squares per acre.

The results of the 1965 study suggest that if populations of overwintered female boll weevils occur at levels no greater than 10 to 20 per acre, there would be a period about 45 days after the first one-third grown squares appear before damage would be sufficient to reduce yields. In the dryland experiment utilizing the Lankart Sel. 57 variety of cotton, 45 days was a sufficient production period for maximum fruit set (yields). In irrigated culture using indeterminate varieties, 45 days probably would not be an adequate amount of production time. In this situation it is probable that the second weevil generation might cause considerable economic damage.

1966–68—In each of these three seasons, the overwintered female populations were great enough to produce a sufficient number of first generation weevils (Figures 7, 8 and 9) to cause considerable crop damage. The smallest first generation peak recorded was about 1,000 individuals per acre in 1968, and 55 percent of the squares were attacked (Figure 4). In each of the 3 years, the first weevil generation hindered boll set;

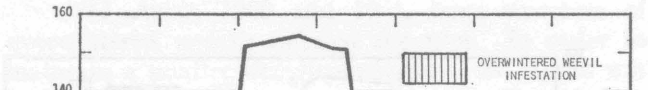

Figure 5. The relationship of seasonal squaring in a 1/22-acre plot of cotton to several generations of the boll weevil, 1965. The shaded and unshaded areas in the figure indicate the portions of the squaring curve exposed to each generation.

and as a result of poor boll retention, a secondary squaring curve was re-initiated after 50 days (Figure 4). Ample squares were consequently provided for a third generation.

It seems that when overwintered boll weevil populations are of sufficient size to produce a damaging first generation, the resultant failure to set a "boll load" causes the cotton to re-initiate fruiting late in the season. This fosters the development of later weevil generations. As the incidence of diapause rapidly increases in the later generations, the secondary fruiting curve becomes important to the development of great numbers of potential overwintering weevils.

During the 1966–68 studies, the smallest female overwintered weevil population averaged 40 females per acre, and yet these were sufficient to produce a first generation population that punctured 55 percent of the squares. In 1965, a population of 22 females per acre did not give rise to an economically damaging first generation. Therefore, the economic threshold of overwintered weevils that are to produce a damaging first generation apparently is in excess of 22 females per acre.

Implications of Population Study Findings

The significant point that emerges from the population studies of the boll weevil is the relative predictability of the time during the fruiting period of cotton when damaging numbers of weevils will develop from various numbers of overwintered female insects. The fruiting sequence of cotton and the reproductive characteristics of the pest interact to produce an orderly emergence phenomenon of each weevil generation that should help in planning pest management programs. The data suggest that for much of the production of Texas dryland areas, the primary goal of boll weevil control should be to reduce overwintered populations to 10 to 20 females per acre. If this could be accomplished, infestations in cotton by the overwintered and first generation of weevils should not affect yields. The 10 to 20 female-per-acre population level might be achieved with applications of an organo-phosphate insecticide applied at squaring and at intervals thereafter; but with such an approach, the beneficial arthropod populations would be destroyed, and dangerous bollworm and tobacco budworm infestations may develop. On the other hand, the use of the fall diapause control program to reduce overwintered boll weevils carries fewer of the hazards associated with inseason treatment. Results obtained on the High Plains of Texas indicate that overwintered populations can be reduced with this program to much less than the 10 to 20 female-per-acre threshold. Control of the potential diapausing generation, together with appropriate defoliation and desiccation, could remove the boll weevil threat from the dryland areas. Inseason control for the pest, and all of the attendant secondary insect problems that develop because of the insecticides

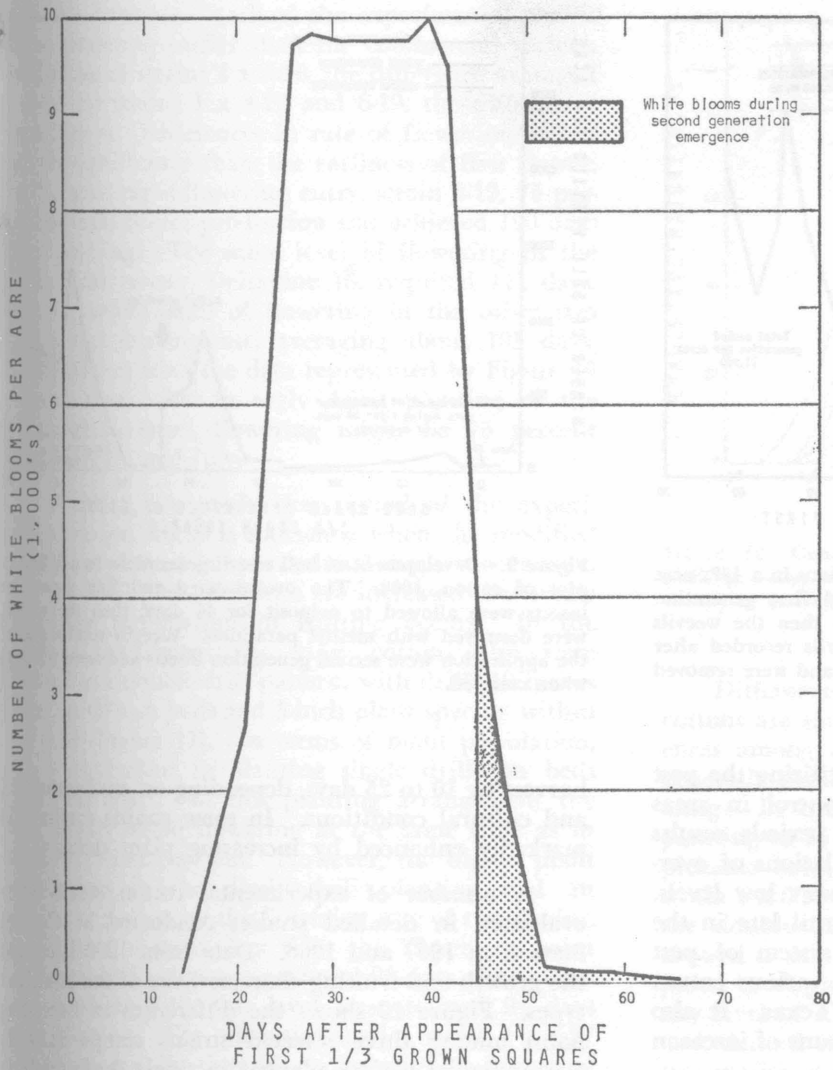

Figure 6. The relationship of the flowering in a 1/22-acre plot of cotton to the emergence period of second generation boll weevils, 1965.

applied for a key pest, would be substantially eliminated if areawide programs of diapause control, defoliation and dessication were practiced at the appropriate times of season in the dryland production areas.

With irrigated cotton and the current relatively indeterminate varieties, the problem is more difficult. As a longer production period is utilized to produce greater yields, the second generation of weevils presents a threat to production. Weevils emerging after the first 45 days of squaring, while not constituting much of a threat to dryland production, would be a serious problem in the irrigated, relatively indeterminate cottons. For this cotton to escape damage by the second generation, it would be necessary for a fall diapause program to reduce overwintered numbers to considerably below the 10 to 20 female-per-acre level that might be acceptable in dryland production. Since the production period for irrigated cotton extends into the time of season when incidence of diapause is high, the timing and number of insecticidal treatments needed to reduce diapausing weevil population would be much more critical.

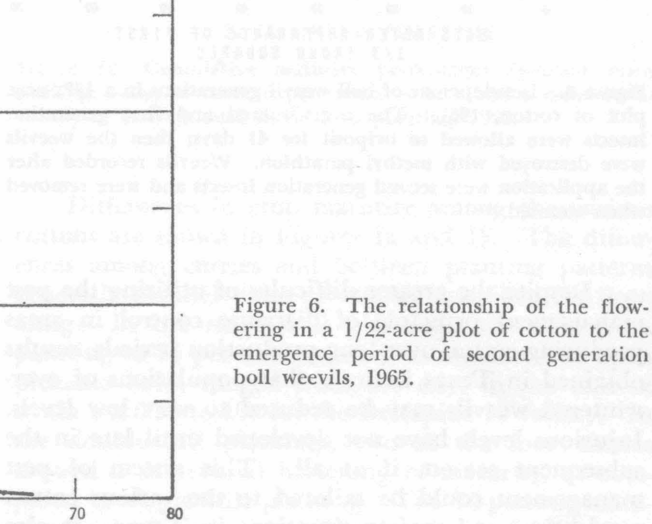

Figure 7. Development of boll weevil generations in a 1/22-acre plot of cotton, 1966. The overwintered and first generation insects were allowed to oviposit for 41 days; then the weevils were destroyed with methyl parathion. Weevils recorded after the application were second generation insects and were removed when counted.

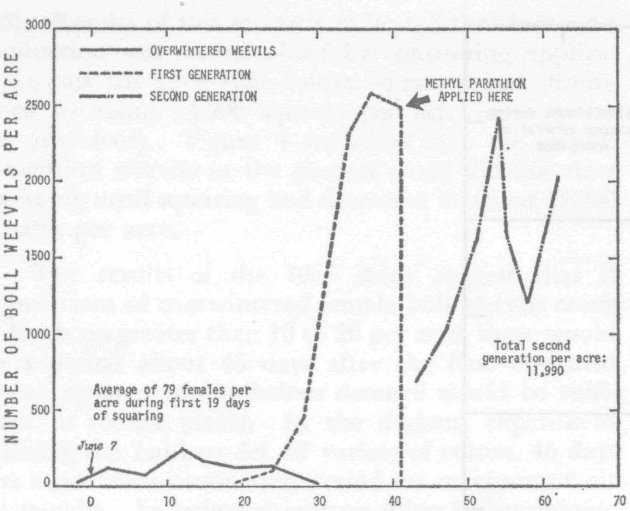

Figure 8. Development of boll weevil generations in a 1/22-acre plot of cotton, 1967. The overwintered and first generation insects were allowed to oviposit for 41 days; then the weevils were destroyed with methyl parathion. Weevils recorded after the application were second generation insects and were removed when counted.

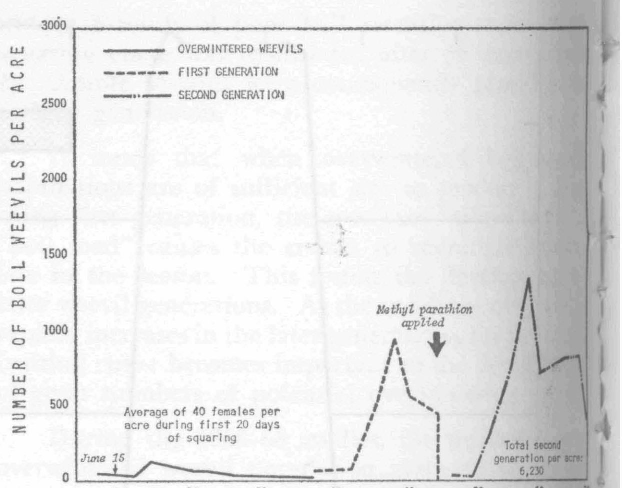

Figure 9. Development of boll weevil generations in a 1/22-acre plot of cotton, 1968. The overwintered and first generation insects were allowed to oviposit for 44 days; then the weevils were destroyed with methyl parathion. Weevils recorded after the application were second generation insects and were removed when counted.

Despite the greater difficulty of utilizing the pest management principle of diapause control in areas producing cotton over long production periods, results obtained in Texas indicate that populations of overwintered weevils may be reduced to very low levels. Injurious levels have not developed until late in the subsequent season, if at all. This system of pest management could be tailored to the various cotton production and variety situations in Texas. It also might be used to eliminate a great amount of inseason chemical control for the boll weevil.

Although the pest management approach for reducing diapausing boll weevil populations seems tenable for both the dryland and irrigated areas of Texas, recent developments by breeders at Texas A&M University offer the means for greatly improving this technique. Certain genetic stocks of cotton have been selected that mature remarkably early. This earliness does not result in a loss in yield if the cotton is grown in high density culture. Such cottons may provide a significant breakthrough in pest management schemes aimed at reducing boll weevil populations.

Plant Breeding and Its Role in Pest Management

Cotton breeders in the Department of Soil and Crop Sciences at Texas A&M University have developed a series of experimental strains which, compared to predominant commercial varieties, are earlier in the initiation of flowering and set fruit more rapidly. In some of these strains, the boll maturation period also has been shortening. These modifications in fruiting habit produce an acceleration of the overall fruiting period, hasten crop maturity and advance harvest by 10 to 25 days, depending on environmental and cultural conditions. In some strains earliness is markedly enhanced by increasing plant density.

A number of experimental cotton stocks were evaluated in detailed studies conducted at College Station in 1967 and 1968. Data from 1968 illustrate the growth and fruiting characteristics of the modified types. Figure 10 shows the differences in flowering habit among three selected strains compared with a commercial variety planted in single drills on beds 40 inches apart. Plants in the drill were singly spaced

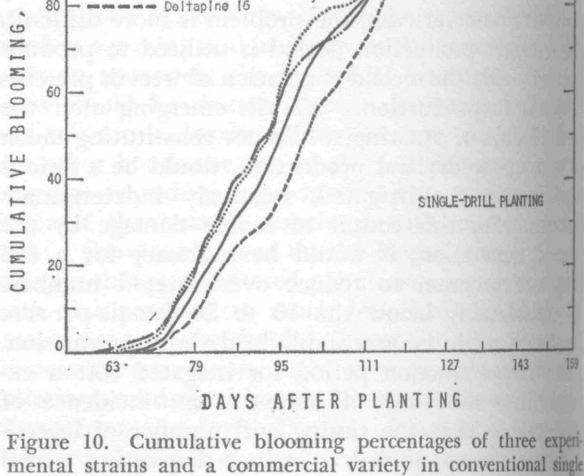

Figure 10. Cumulative blooming percentages of three experimental strains and a commercial variety in conventional single drill planting, 1968.

at 5-inch intervals. Each of the experimental strains began flowering earlier than the commercial variety. In the case of strains 1 x 6-56, the difference averaged 5 days; for strains 1 x 4-27 and 6-19, the differences were 2 days. Differences in rate of flowering are of greater significance than the earliness of first flower. In the most rapid-flowering entry, strain 6-19, 75 percent of total flower production was achieved 100 days after planting. The same level of flowering in the commercial variety, Deltapine 16, required 111 days. The 75-percent level of flowering in the other two strains was intermediate, averaging about 105 days. Extrapolation from the data represented by Figure 10 suggests that, with an early April planting of the experimental types, flowering might be 75 percent completed by mid-July.

Although the production period of the experimental cotton stocks is shortened when the modified cottons are planted in conventional single row culture, it is not until plant densities are increased that really significant acceleration in fruiting occurs. In the previous experiment the same cottons also were planted in a double-drill pattern, with drills 10 inches apart on 40-inch beds and 5-inch plant spacing within the drill (Figure 11). In terms of plant population, this is equivalent to planting single drills on beds 20 inches apart. In this planting arrangement the four entries began flowering at the same time as in the conventional system. However, the higher plant populations in the double-drill planting had an accelerating effect on the flowering rate of two strains. In the case of strain 1 x 6-56, the 75-percent point of bloom production was achieved 98 days after planting; in strain 6-19, this level was attained 94 days after planting. The other two entries, strain 1 x 4-27 and Deltapine 16, showed no increase in flowering rate when planted in the double-drill row.

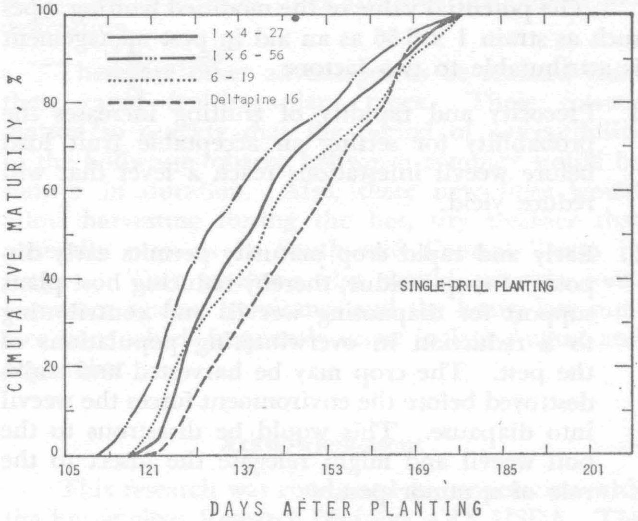

Figure 12. Cumulative maturity percentages (percent open pickable bolls) of three experimental strains and a commercial variety in conventional single drill planting, 1968.

Differences in crop maturity among the various cottons are shown in Figures 12 and 13. The differences among entries and between planting patterns generally parallel those previously described for flowering. In the single-drill plantings, the days from planting to 75 percent maturity, as measured by open pickable bolls, ranged from 148 days in the case of strain 1 x 6-56 to 160 for the Deltapine 16 variety. In the double-drill plantings, two of the four entries showed a substantial hastening of maturity, as compared to single-drill planting. The 75-percent maturity level of strain 1 x 6-56 was advanced by 5 days, and that of strain 6-19, by 18 days. For the other two entries, strain 1 x 4-27 and Deltapine 16, maturity was not affected by plant density.

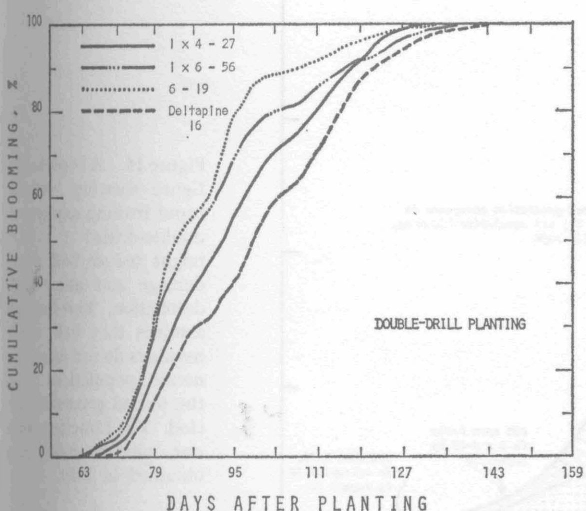

Figure 11. Cumulative blooming percentages of three experimental strains and a commercial variety in double drill plantings (two rows per bed), 1968.

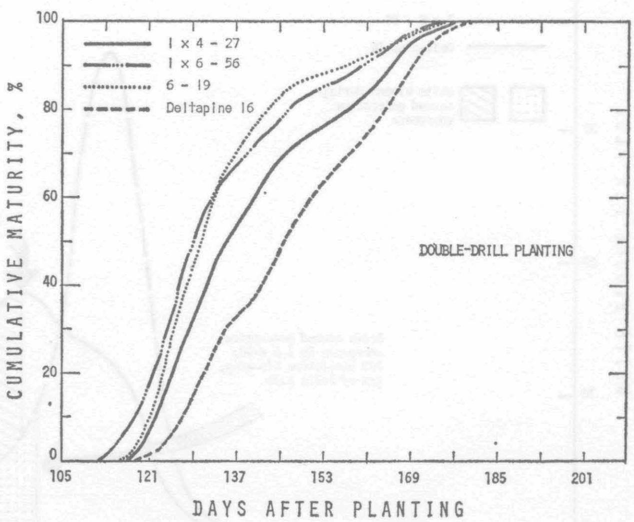

Figure 13. Cumulative maturity percentages (percent open pickable bolls) of three experimental strains and a commercial variety in double drill planting (two rows per bed), 1968.

The potential value of the modified fruiting types such as strain 1 x 6-56 as an aid in pest management is attributable to two factors:

1. Precocity and rapidity of fruiting increases the probability for setting an acceptable fruit load before weevil infestations reach a level that will reduce yield.

2. Early and rapid crop maturity permits early disposal of crop residue, thereby reducing host plant support for diapausing weevils and contributing to a reduction in overwintering populations of the pest. The crop may be harvested and stalks destroyed before the environment forces the weevil into diapause. This would be disastrous to the boll weevil and might relegate the insect to the role of a minor pest.

The importance of rapid fruiting and early maturity in combating the boll wevil can be seen in Figure 14. This is a hypothetical presentation. However, the figure has been constructed from actual data obtained in independent studies of the boll weevil and of the fruiting performance of two genotypes of cotton. The flowering sequence of these genotypes is given in Figure 14 with the second generation emergence periods indicated during the periods of flowering. The flowering data were recorded in 1968 from irrigated plots of double-drilled Deltapine 16 and experimental strain 1 x 6-56. Yields in both genotypes were comparable. The graph assumes that the second generation of the insect developed from an overwintered weevil population of 22 females or less per acre and that neither the overwintered generation nor the first generation hindered fruit set.

The population dynamics studies presented earlier in this paper show that the first second generation weevils began emergence 45 days after the first one-third grown squares appeared in the cotton. This would be approximately 33 days after the initiation of first flower. In cotton planted April 1, the beginning of the second generation emergence period in strain 1 x 6-56 would be about July 5; in Deltapine 16, about July 9. At these times about half of the bolls in the strain 1 x 6-56 would be 12 days or older and consequently safe from boll weevil damage. Deltapine 16, on the other hand, would have about 30 percent of its bolls past the critical weevil damage stage. By August 10, approximately 60 percent of the bolls should be open in strain 1 x 6-56, and a defoliant could then be applied. In the Deltapine 16, it would be about 18 to 20 days later before a defoliant application could be safely made.

The accelerated production of strain 1 x 6-56 can allow significant early fruit set before boll weevil populations attain large numbers. And, as a result of the latter, strain 1 x 6-56 might be harvested 3 weeks earlier than Deltapine 16 or other similar commercial varieties. The early destruction of stalks of strain 1 x 6-56 in turn would greatly reduce the winter carry-over of the pest.

Perhaps, the earlier defoliation and harvest would be sufficient to lower the population of overwintered female weevils to less than 10 to 20 per acre the following spring. This would prevent an early season build-up of great numbers of weevils, and the crop should not suffer yield reducing infestation until at least 45 days after the initiation of squaring. By this time, at least half of the yield should be safe from boll weevil damage. A much greater degree of population control

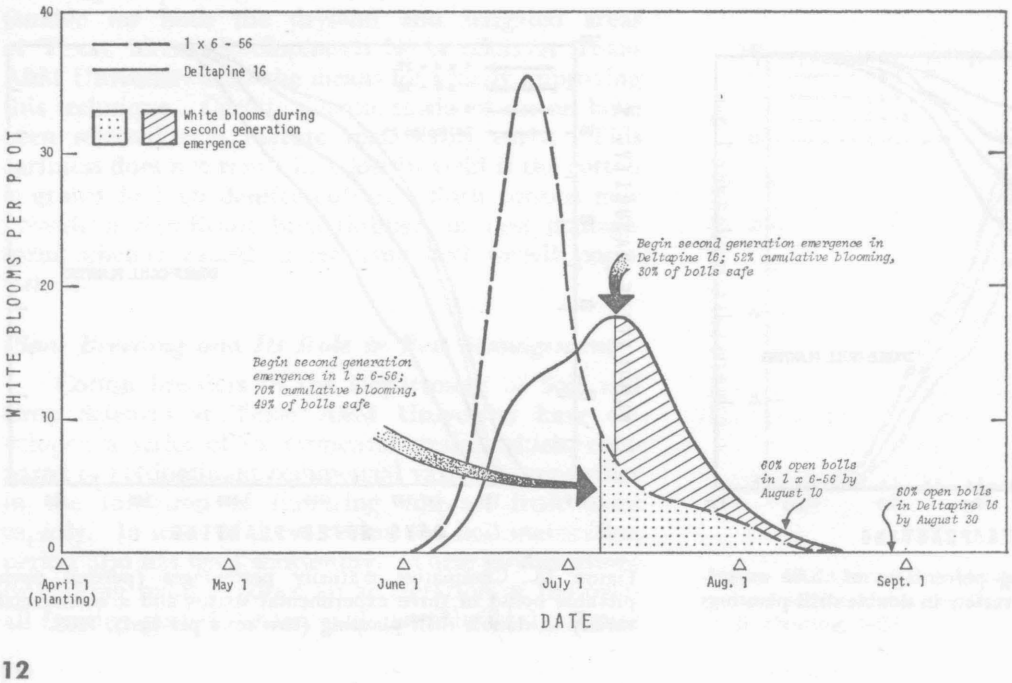

Figure 14. A hypothetical figure showing how the rapid fruiting sequence of double-drilled 1 x 6-56 might reduce boll weevil damage and allow early defoliation. This example assumes that boll weevil numbers do not reach economic populations until the second generation period. The flowering curve was plotted from data obtained in 1968.

could be obtained if several organo-phosphate insecticide applications were made for reproducing and diapausing weevils between July 5 and the time of the defoliation application. This would assure maximum boll protection and further reduce the potential for winter carryover of the pest.

Strain 1 x 6-56 and similar genotypes are experimental cottons. They are not available to growers. Improvements are needed in "turn out" and in fiber quality, and the mechanics of high density planting and tillage are still being researched. Nevertheless, these cottons may hold considerable promise for the future. Acceptable yields might be achieved without extending the production and harvesting periods late into the growing season when the environment forces the weevil into diapause. This would greatly reduce the numbers of potential overwintering weevils. Further reinforcement to this management practice could be gained from limited use of organo-phosphate insecticides during the period of second generation weevil emergence and from areawide defoliation and desiccation.

There are other advantages to be realized from these rapid fruiting plant types. These cottons mature so quickly that the period of susceptibility to the bollworm-tobacco budworm complex would be shorter in duration. Also, these new lines would allow harvesting during the hot, dry weather that generally prevails in South and Central Texas in August. This earliness also would provide some insurance against hurricanes and the heavy late summer rains which frequently occur in late August and September.

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