Population assessment of cotton bollworm in relation to pest control practices

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Long-range studies on cotton bollworm were initiated to develop control recommendations relating damage potential to pest population density, environmental conditions, and the general economics of cotton production. Data from these preliminary studies indicate that the present criteria used in determining the economic threshold for cotton bollworm need to be re-evaluated. The data suggest that higher infestations of cotton bollworm may be tolerated than previously believed.

AGRICULTURAL ENTOMOLOGISTS are recognizing that meaningful insect control recommendations must relate damage potentials to pest population densities, environmental conditions, and the general economics of crop protection. Of these criteria, the effective assessment of pest population densities is most important in the development of satisfactory control programs. This information is essential for short-term control decisions because pests present potentially different control problems at different density levels—involving choices of insecticides, dosages, timing and frequency of applications, as well as the immediate and seasonal financing considerations. From a long-range viewpoint, accurate pest-level estimates are essential because of the variable relationships between population levels of a species and naturally limiting environmental factors.

Short-term control decisions are also affected because inaccurate estimates may result in unnecessary or untimely applications of insecticides. In addition to misspent funds, such unnecessary applications can result in the disruption of parasite and predator activity, which may further complicate the already difficult problem of assessing potential control costs. Thus, if a decision is made to use a broad-spectrum short-residual insecticide, as is frequently practiced in cotton pest control, it must be recognized that a rigid insecticide schedule may be required for the balance of the season because of disruption of the faunal environment.

Decisions to use insecticides should also be economically justifiable. Control costs should not exceed expected losses in yield attributable to potential seasonal population levels of both primary and secondary pests; however, information permitting such decisions is rarely available today.

A serious outbreak of cotton bollworm, *Heliothis zea* (Boddie) in California during 1966 created urgent pressures for information on control. However, the existing bollworm economic threshold (the point at which infestations and the damage they cause justify the financial outlay for control) was obsolete, because it had been developed when highly residual chlorinated hydrocarbon materials could be universally used. Use of such materials was greatly restricted in 1966, and organophosphates were largely substituted for them. Growers and pest control advisors were left without valid criteria for invoking control measures based on use of the relatively newer materials.

Thus many treatments were applied unnecessarily and others too soon or too late. Ineffective materials were often used, and even where good initial kills were obtained, bollworm populations resurged rapidly, necessitating costly multiple treatments.

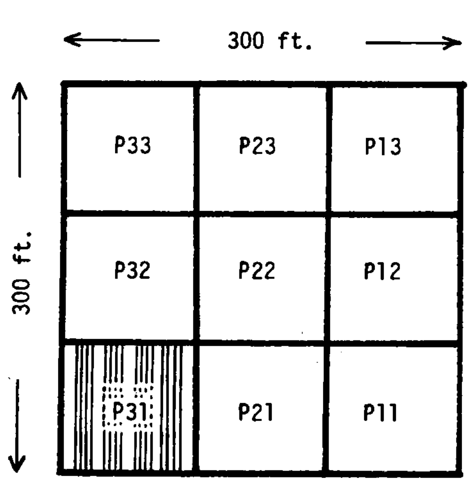
Prospects for effective cotton bollworm control based on use of insecticides alone are now poor for these reasons: (1) bollworm, a traditionally difficult insect to control, is developing resistance to various materials; (2) the effective chlorinated hydrocarbons are being phased out by legal restrictions; (3) the substitute organophosphate materials have serious defects; and (4) generally increasing costs are adding to the economic pressures on all pest control programs.

The broad-spectrum organophosphate materials now being widely used in place of the chlorinated hydrocarbons are more toxic to a wide range of predaceous and parasitic insects that help to suppress cotton pest populations. Furthermore, the effective toxicity periods of many organophosphates are considerably shorter than those of the chlorinated hydrocarbons, resulting in the need for a greater number of applications. This increase in numbers of insecticide applications is both more expensive for growers and more disruptive to the environment.

Farmers and entomologists who do not practice an analytical approach to pest control generally either apply control measures "prophylactically" and automatically by calendar dates, regardless of the rarity of the so-called pest, or make applications because of the presence of pest numbers presumed (but not proven) to be causing economically important

FIG. 1. EXPERIMENTAL DESIGN WITHIN EACH FIELD, LEFT, AND WITHIN EACH PLOT, RIGHT, USED IN 1966 BOLLWORM POPULATION STUDY

PLOT ARRANGEMENT: Nine Sampling Stations, 16 rows/plot.



WITHIN-PLOT SAMPLING STATION: designated plant numbers in sampling sequence.

Inside Row	Outside Row
50 X	X 25
49 X	X 24
48 X	X 23
47 X	X 22
46 X	X 21
45 X	X 20
44 X	X 19
43 X	X 18
42 X	X 17
41 X	X 16
40 X	X 15
39 X	X 14
38 X	X 13
37 X	X 12
36 X	X 11
35 X	X 10
34 X	X 9
33 X	X 8
32 X	X 7
31 X	X 6
30 X	X 5
29 X	X 4
28 X	X 3
27 X	X 2
26 X	X 1

plant injury. Basing insect control programs on calendar dates is a disreputed method; however the widely accepted practice of directly relating (empirically determined) insect levels to presumably reduced crop yields continues virtually unchallenged in most pest control situations—even though such factors as improper irrigation and/or fertilization practices may have equal or greater effect on cotton yields than insect injury.

In summary, effective solutions to cotton pest control problems are not presently available in California because of insufficient knowledge and understanding of cotton environment. This deficiency must be corrected if efficient long-range control programs are to be developed. There is an especially critical need for accurately assessing injury potentials of pests at various population levels. This deficiency in control programs reflects to a great extent our lack of knowledge of the effect of naturally occurring mortality factors on pest populations and of suitable sampling methods for effectively predicting population density levels. The latter requirement, in particular, must be developed to relate known pest numbers to critical mortality factors in their environment *before* meaningful recommendations can be made for use of supplemental natural enemies, and cultural, chemical, or other control measures.

A program was recently initiated to develop long-range cotton bollworm control recommendations. The initial step in this plan is the development of an effective sampling technique to assess larval population densities. The first phase of the study was conducted in insecticide-free cotton in Kern County in the summer of 1966. It consisted of weekly inspection of all portions of 50 adjacent cotton plants in 2 adjacent rows selected randomly from sixteen 100-foot rows in each of 9 plots planted as 4 and 4 skip-row cotton (fig. 1). Initially, four fields were included in the survey on the premise that a sufficiently high bollworm population level would develop in at least one of them to permit accumulation of data amenable to statistical analysis. As plant growth increased with the advance of the season, all fields but one were abandoned because this was all that could be studied with the available resources and manpower. At the time of maximum plant growth, observations in just a single field required over 110 man-hours per 450 plants.

Weekly observations were made beginning June 20. Data obtained before July 25 are not included because *H. zea* larval population densities were extremely low during that period. Data were summarized as larval totals per 50-plant counts, and an arithmetic mean was then obtained from nine replicates. This mean was doubled to obtain the number of larvae per 100 plants, the normal basis for assessing *H. zea* larval populations.

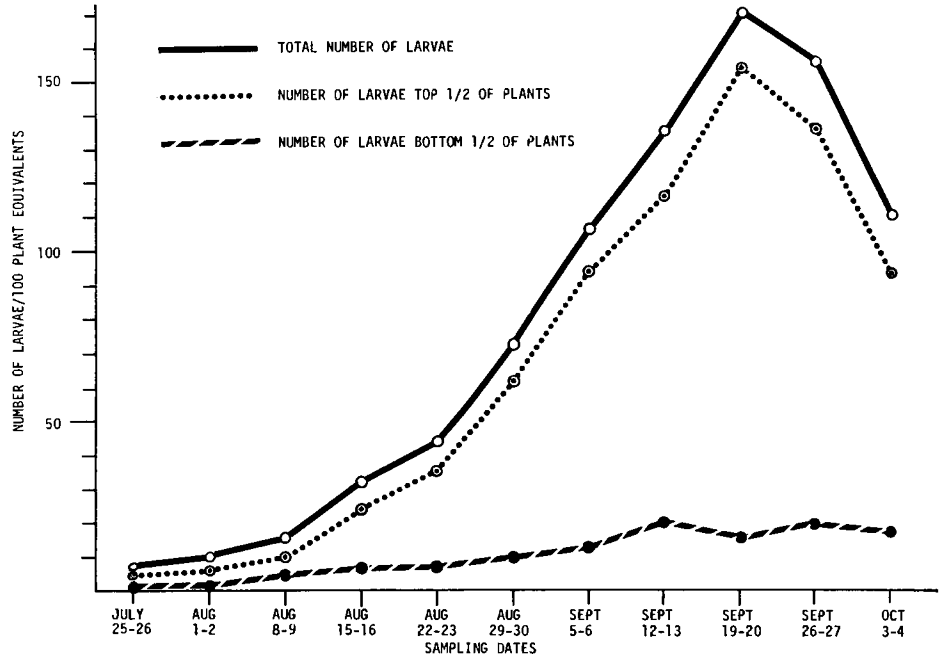


FIG. 2. SEASONAL ABUNDANCE OF BOLLWORM LARVAE AND THEIR DISTRIBUTION ON UPPER VERSUS LOWER HALF OF COTTON PLANTS, MUIR FARM, ROSEDALE, CALIFORNIA, 1966.

The outlined procedure was followed to determine the variation of larval populations between areas in the same fields, and between and within plants in the same area of a field. Reasonable estimates of initial and surviving *H. zea* larval populations cannot be made until this variation in distribution of larvae is precisely determined.

The data obtained in the 1966 study revealed first, that in the study field there was a definite pattern to the spatial distribution of the bollworms, which were found predominantly clustered in bolls and squares on the upper halves of the plants (fig. 2; tables 1 and 2). Even at exceptionally high population densities in September, the 4th-, 5th-, and 6th-instar larvae remained for the most part on the upper halves of the plants (table 1). At the same time, few larvae were found on leafy portions of the plants, including terminal growth. This was true even where high larval populations occurred on plants with abundant new growth on the lateral branches on their lower halves. The fewer larvae found on blossoms than on squares and bolls are important in the development of a useful sampling plan (table 2). Although this observation in particular differs from several previous reports on *H. zea* larval distribution, our report is believed to be representative of an actual situation, because comparable larval numbers were found in small, medium, and large bolls with no indication of significantly greater numbers found on small bolls. If more larvae had survived on blossoms than indicated by the sample, the number of larvae per small boll would have been significantly greater than that found.

The second point of special interest in the 1966 data concerns numbers of *H. zea* larvae that can be economically tolerated in cotton. There are implications in these data that considerably higher infestations can be tolerated than was formerly believed. This was indicated by the yield of 1,056 lbs of lint cotton per acre from the very areas where extremely high larval population densities were recorded. Even if consideration is limited to those larvae traditionally used in assessment of bollworm infestations (larvae ½-inch or less in size), the population exceeded 49 per 100 plants for 6 weeks, 20 per 100 plants for 8 weeks, and 4 per 100 plants for 10 weeks (larval sizes A and B, table 1). Under existing criteria, larval levels over this 10-week period would have been considered "economic" and therefore subject to insecticide treatment; that is, on any given date over this 10-week period, effective control of larvae with insecticides presumably would have prevented sufficient crop loss to more than justify chemical control costs. But this presupposes effective and residual control, which probably would not have been the case because the field was in an area where residual chlorinated hydrocarbon insecticides could not have been used. Thus, multiple applications of short residue organophosphate materials would surely have been necessary if the continuously resurging larval populations

TABLE 1. VERTICAL DISTRIBUTION OF FOUR SIZE CATEGORIES OF BOLLWORM LARVAE ON COTTON PLANTS, MUIR FARM, ROSEDALE, CALIFORNIA, 1966

PLANT HALF	LARVAL SIZE*	SAMPLING DATES AND NUMBER LARVAE RECORDED/100 PLANT EQUIVALENTS											
		JULY 25–25	AUG 1–2	AUG 8–9	AUG 15–16	AUG 22–23	AUG 29–30	SEPT 5–6	SEPT 12–13	SEPT 19–20	SEPT 26–27	OCT 3–4	SEASON TOTALS
Upper	A	+	2	6	13	14	28	44	48	64	54	28	301
	B	2	1	1	3	8	17	18	22	30	30	17	149
	C	2	4	1+	4	10	10	17	28	30	22	26	155
	D	+	1	1+	4	4	7	15	18	30	30	21	132
	Total	5	8	10	24	36	62	94	116	154	136	92	737
Lower	A	+	+	2	2	2	2	4	6	6	8	2	35
	B	0	+	1	2	2	2	2	2	2	4	4	21
	C	+	2	1	2	2	4	3	6	4	4	6	34
	D	0	0	2	2	2	2	3	6	4	4	6	31
	Total	1	2	6	8	8	10	12	20	16	20	18	121
Grand Total		6	10	16	32	44	72	106	136	170	156	110	858

* A = ¼″ or less; B = ¼″ to ½″; C = ½″ to 1″; D = over 1″.
+ = less than 1.

TABLE 2. DISTRIBUTION OF BOLLWORM LARVAE ON FRUITING VERSUS VEGETATIVE PORTIONS OF COTTON PLANTS*, MUIR FARM, ROSEDALE, CALIFORNIA, 1966

PLANT PART	SAMPLING DATES AND NUMBER LARVAE RECORDED/100 PLANT EQUIVALENTS											
	JULY 25–26	AUG 1–2	AUG 8–9	AUG 15–16	AUG 22–23	AUG 29–30	SEPT 5–6	SEPT 12–13	SEPT 19–20	SEPT 26–27	OCT 3–4	SEASON TOTALS
SQUARES	2	4	4	13	14	30	48	56	78	68	38	355
BLOSSOMS	1	2	2	2	4	4	8	8	10	10	4	55
BOLLS	2	2	4	8	16	26	33	47	60	52	42	292
LARVAL SUBTOTAL	5	8	10	23	34	60	89	111	148	130	84	702
LEAVES												
OLD	0	0	0	0	1	1	2	3	2	4	4	17
NEW	+	0	0	0	+	0	1	+	0	+	1	2
TERMINALS	0	+	+	1	1	1	2	2	2	1	1	11
STEMS	0	0	0	0	0	0	+	+	2	1	2	5
LARVAL SUBTOTAL	+	+	+	1	2	2	5	5	6	6	8	35
TOTAL LARVAE	5	8	10	24	36	62	94	116	154	136	92	737

* Includes only larvae on upper ½ of plants.
+ = Less than 1.

were to be kept below the existing "economic" level.

In other words, by using an organophosphate material, the grower would almost certainly have been forced onto an insecticidal treadmill which would have cost him substantially more money than he expected to spend when he initiated chemical control.

In recent years, many San Joaquin Valley cotton growers have been caught on such insecticidal treadmills and have suffered severe economic loss. There is particular hazard where organophosphate materials are applied at the traditional economic threshold against bollworm populations that are under heavy pressure from predators. In former times, such populations could be controlled with residual chlorinated hydrocarbon insecticides with little or no danger of bollworm resurgence even where predators were eliminated. But the organophosphate materials have considerably less residual toxicity, and where they are applied, bollworm populations often resurge very rapidly. Growers must realize that because of this factor the economics of bollworm control have changed a great deal. They must learn to tolerate borderline infestations that are under heavy predator attack, or accept the possible alternative of costly, repeated insecticide treatments. A single, untimely treatment can set off a problem of much greater severity than the one from which growers might initially be trying to protect their crops.

The real significance of the study reported here is found in the yield data because levels of larval populations recorded on this untreated cotton are of practical importance only when related to the plot yield of 1,056 lbs of lint cotton per acre. The U. S. Department of Agriculture estimates the mean production costs of lint cotton grown in the San Joaquin Valley at $0.310 per lb, and the mean price paid for the same cotton at $0.343 per lb. Thus, in the study plot, there was an estimated net profit of approximately $35 per acre from an area which by all existing criteria suffered from a devastating infestation of bollworm. Nevertheless, there was no uninfested control with which to compare yield, and a higher amount of cotton might have been produced in such a plot.

This raises the following questions: (1) Could the grower have effectively controlled the heavy population with multiple organophosphate treatments? (2) Would he have actually aggravated the situation with such a program? (3) How much would such a program have cost? (4) Would the cost have been recovered and a profit realized through increased yield? It is apparent that these are questions that require immediate and intensive analyses. Certainly with most of our cotton growers having no alternative but to use organophosphate materials, traditional economic levels for bollworm must be critically re-examined and perhaps new ones established.

Two questions

In spite of its limited nature, this study has raised two significant questions. First, if spatial distributions of bollworm larvae on cotton plants are not random, how effective are sampling techniques that are based on assumed random distributions? The evidence presented here of larvae being found mainly on fruiting bodies on the upper half of cotton plants suggests that assessment of *H. zea* larval population densities may be improved by incorporating this type of information into a revised sampling technique.

The other important question that has been raised is whether the traditional economic injury level for *H. zea* on cotton is too low, i.e., can more larvae be economically tolerated? This point has already been discussed, but it must be given additional consideration because under an improved sampling technique more larvae will be found per inspected plant.

The preliminary data reported herein indicate that under present conditions we are merely at the beginning of our efforts to obtain the total knowledge necessary to develop meaningful control recommendations for *H. zea* in California. In particular, there is much to be learned about the actual damage-potential from various levels of cotton bollworm field populations and the economics of their control. The intensive analysis of this situation is perhaps the most critical aspect of California cotton pest control research today.

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