B-1048
February
1966

Comparative Effectiveness of Certain Insecticides for Killing Bollworms and Tobacco Budworms

Perry L. Adkisson and S. J. Nemec
Respectively, professor and research assistant, Department of Entomology

Summary

The first significant evidence of the development of resistance by the bollworm, *Heliothis zea* Boddie, to insecticides other than DDT was determined in 1965. The bollworm was found to possess resistance to endrin, Sevin, strobane-DDT and toxaphene-DDT. The tobacco budworm, *Heliothis virescens* (F.), previously had been known to be resistant to these insecticides. However, an even greater level of resistance was developed by the tobacco budworm to these toxicants during the 1965 growing season. Laboratory evaluations were made to determine the efficiency of a great number of insecticides and insecticidal mixtures for killing resistant bollworms and tobacco budworms. Results indicated that mixtures of methyl parathion or Azodrin with endrin, Sevin, strobane, toxaphene or strobane-DDT and toxaphene-DDT showed great promise for controlling the two species. Methyl parathion or Azodrin alone also were highly effective in killing bollworm and tobacco budworm larvae when used in appropriate quantities.

Introduction

The continued development of insecticide resistance by the bollworm and the tobacco budworm is still one of the most serious problems faced by Texas cotton producers. These two pests continued to develop resistance to many of the most commonly used insecticides during the 1965 growing season. Most producers, however, prevented damaging losses from occurring by using certain of these toxicants. This occurred not because the bollworm and tobacco budworm had become less resistant to the insecticides, but because the populations generally were small. Under such conditions, it is necessary to kill only a relatively small percentage of the population to prevent crop loss. When the bollworm and tobacco budworm populations again attain great numbers and persist in cotton for periods of several weeks, control may be extremely difficult to obtain with most of the chlorinated hydrocarbon and carbamate type insecticides.

The tobacco budworm was first reported to have developed resistance to DDT in Texas in 1961 and the bollworm in 1962 (Brazzel, 1962, 1963a). Since this time, the tobacco budworm has developed varying levels of resistance to endrin, Sevin, strobane-DDT and toxaphene-DDT (Adkisson, 1964; Adkisson and Nemec, 1965). Until the present there has been only slight evidence that Texas bollworms were developing resistance to any of the commonly used cotton insecticides other than DDT (Adkisson and Nemec, 1965). The present study shows that this situation no longer is true.

Methods and Materials

Bollworm and tobacco budworm moths were collected almost daily during the growing season from light traps stationed in cotton fields near College Station. Larval progeny of these adults were reared on the wheat germ diet of Adkisson et al. (1960). The diet was fortified with Vanderzant's Insect Vitamin Fortification as supplied by Nutritional Biochemicals Corporation, Cleveland, Ohio. The larvae were reared in continuous illumination at 80± 5° F. Only third and fourth instar larvae which weighted between 25 and 60 mg. were tested.

The first method of testing involved direct application of microgram quantities of each insecticide to the dorsal thoracic surface of each larva. Serial dilutions of selected insecticides in acetone solution were prepared and applied in scalar doses to individual larva in 1-μl droplets. Immediately after treatment, each larva was returned to the rearing vial. Mortality records were made 48 hours after application of insecticides. Untreated control groups were maintained for each treatment series. This was done so that treatment mortalities could be adjusted by Abbott's (1925) formula to correct for any natural mortality occurring in the test population. Doses were replicated at least four times,

TEXAS A&M UNIVERSITY
TEXAS AGRICULTURAL EXPERIMENT STATION • R. E. Patterson, Director, College Station, Texas

with each replicate generally including 25 or more larvae. LD_{50} values were computed from certain of the collected data by the Data Processing Center, Texas A&M University.

The second method of testing involved the use of potted cotton plants. Individual plants were sprayed with a hollow-cone nozzle calibrated to deliver the equivalent of 3.5 gallons of water-emulsion spray mixture per acre. The plants were allowed to dry for 1 to 2 hours in the open air before being transported to a continuously light room maintained at 80± 5° F. Fourth instar larvae weighing between 40 and 60 mg. were placed on the leaf surfaces and held singly in small snap-on type plastic screen cages of about 1½ inches in diameter. Treatments were replicated three times with each replicate including 20 larvae. Mortality records made 48 hours after treatment were adjusted according to Abbott's (1925) formula to correct for natural mortalities occurring in untreated control groups.

Results and Discussion

Results, summarized in Table 1, show the percentages of bollworm larvae killed with each concentration of insecticide for the years 1962 through 1965. Percentages of larvae killed with any given concentration of each insecticide generally were smaller in 1965 than in previous years. This means that greater dosages of each insecticide were required in 1965 to produce comparable mortalities than in previous years.

Similar results for the tobacco budworm are presented in Table 2. These data show that the tobacco budworm also gained in resistance to the selected insecticies. Generally, greater dosages of each insecticide were required in 1965 than in previous years to obtain comparable percentages of larvae killed.

The LD_{50} value is the calculated amount of insecticide required to kill 50 percent of a treated population. This statistic provides the best means for measuring an increase in resistance by an insect population to a specific toxicant. LD_{50} values calculated from the data presented in Tables 1 and 2 are given in Table 3. The values are expressed on the basis of micrograms of insecticide per gram of larva.

These results show that the bollworm has developed a high level of resistance to most of the insecticides tested. An estimate of the magnitude of increased resistance by the population may be gained by dividing the 1965 LD_{50} value by the LD_{50} values of 1960. This type calculation indicates that the bollworm in 1965 was 33,333-fold more resistant to DDT, 13-fold more resistant to endrin, 4.5-fold more resistant to Sevin, 20.8-fold more resistant to strobane-DDT and 11.5-fold more resistant to toxaphene-DDT than in 1960. This increased resistance has mostly occurred since 1964 (Adkisson and Nemec, 1965) and as will be shown later in the present report the percentage of larvae killed in the 1965 tests with the above materials were smaller than in 1964.

LD_{50} values for the tobacco budworm for 1961 and 1965 also are reported in Table 3. These show that the tobacco budworm population also is highly resistant to the insecticides tested. The tobacco budworm during 1965 was 127-fold more resistant to DDT, 215.7-fold more resistant to endrin, 181.6-fold more resistant to Sevin, 15.2-fold more resistant to strobane-DDT and 7.5-fold more resistant to toxahpene-DDT than in 1961. Needless to say, field control of large populations of the tobacco budworm with these insecticides is practically impossible.

The decreased effectiveness of these insecticides

TABLE 1. COMPARATIVE MORTALITIES OF THIRD AND FOURTH INSTAR BOLLWORM LARVAE PRODUCED BY CERTAIN INSECTICIDES 48 HOURS AFTER TOPICAL APPLICATION. LARVAE WERE PROGENY OF ADULTS COLLECTED IN LIGHT TRAPS NEAR COLLEGE STATION

		Dosage, µgs per larva									
Compound	Year[1]	0.625	1.25	2.5	5.0	10.0	20.0	40.0	80.0	160.0	320.0
		Percentage mortalities									
DDT	1962						42.2	50.6	50.6	49.4	75.9
	1963					30.6	48.1	43.9	48.1	57.1	55.1
	1964							10.1	27.3	35.4	29.3
	1965							12.4	8.3	17.5	9.3
Endrin	1962	47.9	75.5	96.9	93.8	100.0					
	1963	8.4	29.5	60.0	78.9	82.3	92.6				
	1964	32.6	54.3	83.7							
	1965			27.1	51.0	59.4	76.0				
Sevin	1962			37.8	46.6	70.0	81.1				
	1963		28.4	45.3	44.2	57.9	71.6				
	1964	20.4	69.4	63.3	84.7	89.8	92.9	94.9	100.0		
	1965		35.9	26.8	27.2	40.6	57.5	58.9	57.4	66.1	78.8
Strobane-DDT	1962				35.6	55.2	77.0				
	1963		3.2	27.7	56.4	61.7	85.1	94.7			
	1964		12.5	39.3	49.5	83.8					
	1965						28.7	54.3	74.5	75.5	
Toxaphene-DDT	1962			23.2	52.5	68.6	78.7	94.9			
	1963			29.0	54.8	63.4	83.9	82.8			
	1964		30.6	43.9	58.2	72.4	87.8	90.8	100.0		
	1965					38.8	55.1	62.2	78.6	86.7	

[1]Data for 1962 from a report by Brazzel (1963b).

TABLE 2. COMPARATIVE MORTALITIES OF THIRD AND FOURTH INSTAR TOBACCO BUDWORM LARVAE PRODUCED BY CERTAIN INSECTICIDES 48 HOURS AFTER TOPICAL APPLICATION. LARVAE WERE PROGENY OF INSECTS COLLECTED IN THE FIELD AND IN LIGHT TRAPS NEAR COLLEGE STATION

		Dosage, μgs per larva									
Compound	Year[1]	0.625	1.25	2.5	5.0	10.0	20.0	40.0	80.0	160.0	320.0
		Percentage mortalities									
DDT	1962						0.0	32.2	12.9	23.6	33.3
	1963						0.0	0.0	19.8	34.1	44.1
	1964						15.1	18.3	16.1	33.3	29.0
Endrin	1962			32.9	56.7	71.1					
	1963		17.5	42.3	51.5	50.5	61.9				
	1964			27.1	33.3	49.0	42.7	34.4	47.9	29.2	
	1965							37.9	27.1	35.7	49.6
Sevin	1962				36.1	35.1	51.5				
	1963				13.2	34.1	42.9	39.6	46.2	33.1	
	1964			7.3	24.0	42.7	32.3	34.4	26.0		
	1965							23.0	20.0	28.0	37.0
Strobane-DDT	1962				11.3	24.7	47.4	49.5	75.3		
	1963				23.2	40.0	52.6	63.2			
	1964						36.1	44.5	50.0	69.4	
	1965							23.0	29.0	34.0	51.0
Toxaphene-DDT	1962				6.2	32.0	48.5	53.6			
	1963				10.8	50.5	45.2	57.1			
	1964				7.1	17.5	35.1	32.9	49.1	55.1	
	1965							28.0	44.0	61.0	69.0

[1]Data for 1962 from a report by Brazzel (1963b).

TABLE 3. DEVELOPMENT OF RESISTANCE BY THE BOLLWORM AND TOBACCO BUDWORM, AS EXPRESSED BY INCREASED LD_{50} VALUES, FROM 1960 TO 1965 TO CERTAIN CHLORINATED HYDROCARBON AND CARBAMATE INSECTICIDES

	LD_{50}, Mg/G of larva			
	Bollworm		Tobacco budworm	
Compound	1960[a]	1965	1961[a]	1965
DDT	0.03	1000+	0.13	16.51
Endrin	0.01	0.13	0.06	12.94
Sevin	0.12	0.54	0.30	54.47
Strobane-DDT	0.05	1.04	0.73	11.12
Toxaphene-DDT	0.04	0.46	0.47	3.52

[a]LD_{50} values for 1960 and 1961 were obtained from reports by Brazzel et al. (1961) and Brazzel (1963a).

from 1964 to 1965 for controlling the bollworm and tobacco budworm is shown by the data presented in Table 4. The materials were sprayed on potted plants at rates equivalent to field dosages. The percentages of larvae of each species killed by equivalent doses of each insecticide were smaller in 1965 than in 1964. This confirms the results obtained by the topical application tests summarized in Tables 1, 2 and 3.

TABLE 4. DECREASE IN EFFECTIVENESS OF CERTAIN INSECTICIDES FOR CONTROLLING BOLLWORMS AND TOBACCO BUDWORMS BETWEEN 1964 AND 1965

Insecticide(s)	Actual toxicant, pounds per acre	Percent kill, 48 hours 1964	1965
	Bollworm		
Endrin	0.25	90	52
Sevin	1.6	93	76
Strobane-DDT	2.0-1.0	90	47
Toxaphene-DDT	2.0-1.0	90	52
	Tobacco budworm		
Endrin	0.4		40
Sevin	1.6	48	31
Strobane-DDT	2.0-1.0	55	19
Toxaphene-DDT	2.0-1.0	45	21

Results obtained in the preceeding study showed that certain of the insecticides recommended in Texas for bollworm and tobacco budworm control are becoming ineffective against resistant strains of the two species. For this reason a number of insecticides and insecticidal mixtures were tested for effectiveness against the resistant insects. These tests were conducted to find materials which may have promise for field use. The insecticides were applied as water emulsions and sprayed at rates equivalent to field dosages.

Results, sumarized in Table 5, list the insecticides in decreasing order of effectiveness which killed more

TABLE 5. INSECTICIDES THAT KILLED MORE THAN 80 PERCENT OF THE FOURTH INSTAR BOLLWORM LARVAE CAGED ON POTTED PLANTS TREATED WITH 3.5 GALLONS OF TOTAL SPRAY PER ACRE, 1965

Insecticide(s)	Actual toxicant pounds per acre	percent mortality, 48 hours
Endrin-Matacil	0.25-0.5	100
Methyl parathion	1.0	100
Toxaphene-m.parathion	4.4-0.31	100
Toxaphene-m.parathion	3.9-1.25	100
Toxaphene-m.parathion	2.0-0.25	100
Azodrin-toxaphene	0.25-1.0	100
Toxaphene-m.parathion	1.94-0.63	98
Strobane-m.parathion	2.0-0.25	98
Toxaphene-m.parathion	4.4-0.63	98
Azodrin-Endrin	0.6-0.25	97
Strobane-DDT-m.parathion	3.0-0.75-0.25	97
Azodrin-Strobane	0.25-1.0	97
Toxaphene-DDT-m.parathion	3.0-0.75-0.25	95
Azodrin	0.8	92
Azodrin-Sevin	0.6-0.8	91
Endrin	0.4	89
Endrin-m.parathion	0.4-0.25	88
Strobane-DDT-m.parathion	2.0-1.0-0.25	88
Methyl parathion	0.50	87
Strobane-Sevin	2.4-0.8	87
Toxaphene-EPN	2.0-0.25	84
Sevin	2.4	82
Azodrin	0.6	81
Guthion-Strobane	0.5-0.3	81

than 80 percent of the test larvae. Insecticides which killed less than 80 percent of the bollworm larvae at rates tested are given in Table 6. The combined data show that methyl parathion or Azodrin must be added to endrin, Sevin, strobane, toxaphene, strobane-DDT, or toxaphene-DDT if great percentages of the larvae are to be killed. However, Azodrin or methyl parathion alone killed approximately 90 percent of the treated larvae when applied at rates equivalent to 0.8 and 0.5 pound, respectively, of actual toxicant per acre. A possible potentiation of the chlorinated-hydrocarbons by Azodrin was indicated by the increased effectiveness of the toxaphene-Azodrin and strobane-Azodrin mixtures over that obtained by the use of the chlorinated-hydrocarbons alone.

Results of similar tests with the tobacco budworm are given in Table 7. None of the insecticides at the rates tested was as effective against the tobacco budworm as against the bollworm. Poor control was produced with the chlorinated hydrocarbons and Sevin. The percentages of tobacco budworm larvae killed in tests with mixtures of methyl parathion or Azodrin with the chlorinated hydrocarbons or Sevin were much greater than where the latter materials were used alone.

These data clearly confirm the evidence summarized in Table 3 which showed that the bollworm and tobacco budworm have developed resistance to the insecticides previously recommended for their control in Texas. A comparison of results obtained in 1965 with those of 1964 show that there has been a considerable increase in resistance during the past year especially in bollworm populations. The bollworm and tobacco budworm are becoming increasingly more difficult to kill with economical dosages of the chlorinated hydrocarbon or carbamate type insecticides. The present laboratory results indicate that these materials will not produce effective field control when used alone or in combination with DDT. This is especially true if large populations are encountered since under these conditions high percentages of the larvae must be killed if control is to be obtained. The data suggest that the chlorinated hydrocarbons or Sevin must be mixed with appropriate quantities of methyl parathion or Azodrin if satisfactory control is to be obtained. These latter two materials also appear to be quite effective when used alone at the appropriate rates.

TABLE 6. INSECTICIDES THAT KILLED LESS THAN 80 PERCENT OF THE FOURTH INSTAR BOLLWORM LARVAE CAGED ON POTTED PLANTS TREATED WITH 3.5 GALLONS OF TOTAL SPRAY PER ACRE, 1965

Insecticide(s)	Actual toxicant, pounds per acre	percent mortality, 48 hours
Toxaphene-DDT-m.parathion	2.0-1.0-0.25	78
Sevin	1.6	76
Sevin	0.8	76
Strobane-EPN	2.0-0.25	73
Toxaphene	6.0	73
Endrin-m.parathion	0.25-0.25	71
Sevin-Thiodan	0.8-0.5	71
Ethyl parathion	0.5	70
Malathion	2.0	65
Toxaphene-TDE	2.0-1.0	64
Chlordane-DDT-m.parathion	1.0-1.0-0.25	64
Thiodan	1.0	58
EPN	0.5	57
Methyl parathion	0.25	55
Sevin-m.parathion	0.8-0.25	53
Endrin	0.25	52
Toxaphene-DDT	2.0-1.0	52
Strobane-DDT	2.0-1.0	47
Malathion-TDE	1.0-1.0	32
Chlordane-DDT	1.5-1.5	26
BHC-DDT	0.9-1.5	24
TDE	1.0	12
DDT	1.0	7

TABLE 7. EFFECTIVENESS OF CERTAIN INSECTICIDES AGAINST FOURTH INSTAR TOBACCO BUDWORM LARVAE CAGED ON POTTED PLANTS TREATED WITH 3.5 GALLONS OF TOTAL SPRAY PER ACRE, 1965

Insecticide(s)	Actual toxicant, pounds per acre	percent mortality, 48 hours
Sevin-m.parathion	1.6-0.25	85
Matacil-m.parathion	0.5-0.25	80
Strobane-DDT-m.parathion	2.0-1.0-0.5	78
Toxaphene-DDT-m.parathion	2.0-1.0-0.5	77
Strobane-m.parathion	2.0-0.25	76
Toxaphene-m.parathion	2.0-0.25	73
Endrin-Azodrin	0.25-0.6	73
Azodrin	0.8	68
Sevin-Thiodan	0.8-0.5	65
Methyl parathion	0.5	63
Endrin-methyl parathion	0.25-0.25	60
Sevin	2.4	52
Azodrin	0.6	47
Endrin	0.4	40
Toxaphene-DDT	2.0-1.0	21
Strobane-DDT	2.0-1.0	19
Chlrodane-DDT	1.0-1.0	15
Malathion	2.0	5
DDT	1.0	5
TDE	1.0	2

Literature Cited

Abbott, W. S., 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18:265-7.

Adkisson, P. L., 1964. Comparative effectiveness of several insecticides for controlling bollworms and tobacco budworms. Tex. Agr. Exp. Sta. Misc. Publ. 709.

Adkisson, P. L. and S. J. Nemec. 1965. Efficiency of certain insecticides for killing bollworms and tobacco budworms. Tex. Agr. Exp. Sta. PR-2357.

Adkisson, P. L., E. S. Vanderzant, D. L. Bull and W. E. Allison. 1960. A wheat germ medium for rearing the pink bollworm. J. Econ. Entomol. 53:759-62.

Brazzel, J. R. 1962. Toxicity of certain insecticides against bollworms and tobacco budworms. Tex. Agr. Exp. Sta. PR 2236.

Brazzel, J. R. 1963a. Resistance to DDT in *Heliothis virescens*. J. Econ. Entomol. 56:571-74.

Brazzel, J. R. 1963b. Effectiveness of several insecticides against bollworms and tobacco budworms. Tex. Agr. Exp. Sta. PR 2281.

Brazzel, J. R., H. Chambers, and P. J. Hamman. 1961. A laboratory rearing method and dosage-mortality data on the bollworm, *Heliothis zea*. J. Econ. Entomol. 54:949-52.

Acknowledgments

The research was conducted in cooperation with the Entomology Research Division, U. S. Department of Agriculture. The technical assistance given by Mrs. Judy Whitley and Mrs. Carol Blanton in conducting these studies is gratefully acknowledged.