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FACTORS AFFECTING ECONOMIC BENEFIT DERIVED FROM USING INSECTICIDES TO CONTROL BOLLWORM, *Helicoverpa zea* (BODDIE)/TOBACCO BUDWORM, *Heliothis virescens* (F.), IN OKLAHOMA 1976-1990

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Abstract

One hundred and thirty one insecticide treatments were applied to cotton and evaluated for control of the bollworm, *Helicoverpa zea* (Boddie) and the tobacco budworm, *Heliothis virescens* (F.) at Chickasha, OK from 1976 to 1990. Yields as lint were also taken. Yields in insecticide treated plots were 9% greater during the 13 years (they were not taken in 1984 and 1989) compared to untreated plots and were not significantly different. This increase did not provide an economic benefit during these years. When killing frosts occurred before day 312 (the 30 year average first frost date) in five (38%) of the 13 years yields of treated cotton were significantly greater than untreated plots in 40% of those years. When frost occurred on or after day 312 as it did in eight (62%) of the years, yields of treated cotton were equal to or greater than untreated cotton in 50% of those years. Mixtures of two and three insecticides were no more effective than each of the insecticides alone against the two pest species.

Introduction

Insecticides were used to control bollworm/tobacco budworm larval feeding damage, hereafter called bollworm/tobacco budworm, at Chickasha, OK, from 1976 to 1990. A wide array of environmental conditions prevailed at this location during this time period.

Bryan (1961) conducted similar tests from 1950 - 1960 against these same pests at many locations in OK, including Chickasha, but no information exists on efficacy of insecticides in the Chickasha area for the past 30 years.

Results of experiments on insecticide efficacy for the past 15 years, 1976 to 1990, were determined; harvest of lint was taken in 13 of those years. Differences in yields of untreated cotton were not always less than treated cotton despite the fact that effective insecticides were used and damage by larvae of the bollworm/tobacco budworm was reduced. We reasoned that environmental conditions played a role, as well as the fact that populations of the bollworm/tobacco budworm were not continuous during the season. In addition we determined profitability of the different insecticides at this location from 1976 to 1990 based on certain assumptions as well as efficacy of 131 insecticide treatments.

Materials and Methods

Formulations of amitraz (Ovasyn), bifenthrin (Capture), *Bacillus thuringiensis*, (Dipel), cyfluthrin (Baythroid), chlordimeform (Galecron), chlorpyrifos (Lorsban), cypermethrin (Ammo), endosulfan (Thiodan), endrin, EPN, esfenvalerate (Asana), fenvalerate (Pydrin), *lambda* cyhalothrin (Karate), methomyl (Lannate), methyl parathion, permethrin (Pounce), profenofos (Curacron), sulprofos (Bolstar), thiodicarb (Larvin), toxaphene were 2,396, 100, formulations containing <15,0OO International units/mg, 240, 479, 479, 360, 240, 959, 479, 79, 288, 120, 216 and 288, 479, 240 and 384, 959, 719, 384, and 959 g/l, respectively.

Cultivators Lockett 4789A (5 years), Paymaster 145 (5 years), Stoneville 213 (4 years) and Cascot B-2 (1 year) were planted during the 15 years. Cold soil temperatures and dry or wet conditions influenced planting date. Agronomic practices (stand establishment, fertilization, and harvest) were similar each year. Plots were irrigated one to two times each year, except 1989, on an "as needed" basis.

All insecticides were applied at 5 gal spray mixture/ha at 2.81 kgs/cm^2 using a John Deere™ 6000 Hi Cycle (Moline, IL). The spray boom was equipped with Spraying Systems hollow cone Tx8 nozzles on 101.5cm centers. Plots were 8 rows (1m apart) wide and 30.48 - 76.2m long arranged in a randomized complete block design with three replicates.

Each plot was sampled for larval feeding damage by examining 100 squares or small bolls selected at random from the upper one half of the plants prior to each spray application. Percent damage was averaged for the season. The number of applications was equal to the number of sampling dates, applications were made at three to six d intervals after the initial application.

Larvae (13 to 50 4th and 5th instar) were collected from cotton during August of 1976- 1980, 1982 and 1984 to determine the percentage of bollworm and tobacco budworm using the presence or absence of the mandibular process [Peterson 1962).

Plots were harvested as soon as possible when maximum yields were ready or as soon as possible after the first freeze. Excessive rains or hail prevented the harvest of seed cotton in 1984 and 1989. The average freeze date (90% probability for 32 °F) for Chickasha, OK, is November 8, day 312) [Koss et al. 1988).

Assumptions for profitability of producing cotton at Chickasha, OK are based on $0.99/kg lint (11 years average price) and a cost of $19.76/ha for each insecticide(s) and application, determined by averaging the cost of insecticides used to control bollworm/tobacco budworm in OK. Percentage yield increase for each insecticide above mean kg of lint/ha in untreated cotton were included in the calculations for profitability of the insecticide application. Linear regression with coefficient of determination (R^2) was computed by programmable calculator on mean percentage damage versus yields in the untreated plots for every year except 1984 and 1989. Also, t at $P_{0.05}$ was computed to determine if there were significant differences between yields of untreated versus treated cotton.

Results and Discussion

Planting dates ranged from day 132 (May 12), 1980, to 171 (June 20), 1986, a difference of 39 days (Table 1). This difference was caused by inclement weather which delayed planting in some of the years tests were conducted. The number of insecticide applications were three in 1985, 1989 and 1990, four in 1977, 1981, 1982, 1984, 1986, 1987 and 1988, five in 1976, 1979 and1983, six in 1980 and seven in 1978; an average of four during the 15 years. Bollworm/tobacco budworm larval populations caused 5% or greater damage to squares and bolls before the first application each year. Damage was caused by the populations present throughout the time sprays were applied. When damage ceased, sprays ceased. No other pest species was present in sufficient numbers in this cotton to cause significant damage during the test period. There were 131 treatments and 15 untreated checks. The earliest application was applied on day 192 (August 1) and the latest was made on day 251 (September 8).

Harvest dates ranged from day 290 to 363. Plots were harvested before the average date of first frost (d 312) in seven (54%) of the 13 years. When frost occurred on or after d 313, as it did in six [46%] years, the yields of treated cotton were equal or greater than the yields of untreated cotton in 50% of those years. Days from planting to killing frost were adequate each year to accumulate sufficient growing degree days (gdd) for complete boll development.

Percent damage squares and small bolls in the untreated cotton [Table 2) indicated extreme variation in insect pressure between years; a low of 1.8% in 1986 and a high of 19.3% in 1977. Mean damaged squares and small bolls were 10% for the 15 year test period. No trends were indicated.

Tobacco budworms and bollworm comprised a mean of 51% and 49% of the larval populations at Chickasha, OK, respectively (data not shown in Table). Percentage ranged from 26% to 87% tobacco budworm in 1967 (46%), 1977 (62%), 1978 (87%), 1979 (50%), 1980 (26%), 1982 (50%) and 1984 (37%). Control of bollworm-tobacco/budworm larvae at this location was directed at both species equally.

Cotton lint yields (Table 2) of the untreated check ranged from 0 (1984 and 1989) to 879.9 kg/ha in 1987. Yields averaged 580.23 kg/ha in the untreated cotton during the 13 years. Based on $0.99/kg lint/ha the untreated cotton was valued at $574.42.

Sprays of fenvalerate and esfenvalerate provided an average of 71% and 62% control against larval feeding damage by the bollworm/tobacco budworm (Table 3). Lint yields increased an average of 8% and 2% for fenvalerate and esfenvalerate, respectively. However, based on average yields and costs of insecticides 4 applications (15 y average) of fenvalerate would result in a $35.56/ha loss. Since yield increases were less for esfenvalerate 4 applications would result in $351.41/ha loss.

Permethrin and cypermethrin provided 58% to 72% percent control (Table 3). Yields of cotton increased 10% and 15% following sprays of permethrin and cypermethrin, respectively. With our assumptions of $48.81/ha application costs and percent yield increase 4 applications of permethrin resulted in a $24.70/ha loss. Cypermethrin yield increases displayed a profit of $6.10/hectare.

Percentage control of bollworm/tobacco budworm feeding damage by fenvalerate, esfenvalerate, permethrin, cypermethrin, cyfluthrin, and thiodicarb were 71%, 62%, 58%, 72%, 72% and 69%, respectively (Table 5). Mean percentage control for bifenthrin and l*ambda* cyhalothrin was 72% and 63%, respectively (data not shown in Table). Control by *lambda* cyhalothrin was 47%, 72% and 70% in 1978, 1988 and 1989, 0.2to 0.05, 0.025 and 0.03 kg (A.I.)/ha, respectively. Control by bifenthrin was 59%, 100% and 33% in 1984, 1986 and 1987, at 0.04, 0.06 and 0.06 kg(A.I.)/ha, respectively (data not shown in table). Percent control was adequate and resistance to the pyrethroids and carbamate was not shown through 1990. Fenvalerate, esfenvalerate, permethrin, cyfluthrin, *lambda* cyhalothrin and thiodicarb did not increase yields more than 13% . This increase did not indicate a profit. In 1978, 1988 and 1989 *lambda* cyhalothrin showed 0%, 26% and unable to determined yield increases, respectively (data not shown in table). In 1984, 1986 and 1987 bifenthrin showed unable to determine, unable to determine and 27% yield increase, respectively. This yield increase resulted in a profit of $125.23/hectare.

In 1977, 1979, and 1980 profenofos, acephate, and sulprofos were tested at 0.56, 1.12 and 0.84 kg (A.I.)/ha respectively, (data not shown in Table). At these rates, 47, 55 and 76% control of the insects and 0, 3 and 12% increase of yields were determined. No profit was shown from these insecticide treatments. In 1976 and 1988 methyl parathion was evaluated at 1.12 kg (A.I.)/ha (data not shown in Table). In 1976 percentage control and increase of yield were 49 and 21%, respectively; in 1988 these same parameters were 21 and 6%, respectively. In 1984 and 1985 tralomethrin was evaluated at 0.012 and 0.021 kg (A.I.)/ha. Percentage control was 70% and 43%, respectively. Cost estimates were not made because these insecticides were not tested for more than 2 years

Thirty-four mixtures of two and three insecticides were tested (Table 4) during the 15. Control with mixtures was approximately equal to control with fenvalerate, esfenvalerate, permethrin, cypermethrin, thiodicarb, cyfluthrin, and *lambda* cyhalothrin. Yields were increased by an average of 4%, which did not indicate a profit. Single compounds generally displayed greater profits than mixtures of 2 and 3 insecticides.

During the 13 years (no yields were taken in 1984 and 1989) the coefficient of determination (R^2) was 0.14 ($P_{0.05}$ = 0.55 for df = 11). It was not significantly different for percentage damaged squares of the untreated check and yield loss (lint kg/ha) for the untreated check. Although insect pressure contributes to yield loss, many other factors (planting date, stand density, nitrogen rate, irrigation schedule and weather) play an important role in the yield response. We suggest that the total effect of these other factors contribute more to yield losses than the larval feeding damage to square and immature bolls. From 1976 to 1990, there were 61, 55, 60, 72, 78, 63, 60, 60, 79, 84, 131, 80, 81, 61 and 47 d (last application to d 312) between last sample date and harvest, respectively.

Significant differences in yields occurred only between treated and untreated cotton in 1981, 1982, and 1986 (23% of the 13 years). There was no significant difference between yields of treated and untreated cotton by t=1.73 (P_0.05=2.179 for 12 df).

Parencia and Cowan (1972) clearly showed the value of cotton insect control with insecticides by increasing yields 51% over the untreated cotton in the Blacklands area of Central TX for 31 years from 1939-1970. This increase in yield was attributed to control of all insect pests present. Yield data from the present study in the Chickasha area of South Central OK suggest insecticides were not needed 77% of the time (10 of 13 years) when frost occurs on day 312 or later.

In 1992, a telephone survey was conducted to determine if results from these efficacy trials reflect the type of insect control followed by the cotton producers in the immediate vicinity of South Central Oklahoma Research Station. Only the producers that farmed during the 15 year period were questioned. The survey emphasized bollworm/tobacco budworm control and early boll set. Survey results showed that these producers were aware of the importance of earliness to produce a cotton crop. Triple-treated (two fungicides and an insecticide) seed was widely planted to protect seedling plants from thrips and plant disease to produce early boll set. Little, if any, spraying occurred during this 15 year period to control bollworm/tobacco budworm or any other insect pest after cotton started blooming.

The ability of the cotton plant to recover from a loss of substantial percentages of fruit and still produce a normal crop is well documented [Dunnam et al. 1943, Eaton 1955 and Hammer 1941). The physiological characteristic of setting (40 to 60 % of the fruit are lost by natural physiological processes) fruit and the indeterminate growth of the cultivars compensated for larval feeding damage.

Under ideal fall weather conditions sufficient heat units (>2500gdd) accumulate to allow the cotton to compensate for bollworm-/tobacco budworm damage, resulting in no significant yield differences. However, in 1981, 1982, and 1986 significant yield differences occurred in treated cotton compared to untreated cotton because insufficient heat units were determined. Continual pressure by bollworm/tobacco budworm can delay maturity, but early or late season frosts can either prevent or have no effect on yields.

Insecticide applications during this 15 year period were applied every three to six d until bollworm/tobacco budworm larval feeding damage ceased. Differences in percentage control occurred annually, however, yields indicate insect control was only needed 23% of the time when frost occurred on d 312 or later. Yields of treated plots in 13 of the 15 years were greater than 9% of the untreated plots. Monetary losses from bollworm/tobacco budworm control during this 15 year period emphasize the importance of sampling each field for damage levels before applying an insecticide. This practice reduces unnecessary insecticide usage and helps ensure that recommended insecticides continue to control the bollworm/tobacco budworm in OK.

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Table 1. Planting, applications of insecticides, sampling and harvest calendar d for cotton, Chickasha, OK. 1976-1990.

		Applications and Sampling D			D of
Year	**Planting D**	**First**	**Last**	**Harvest**	**Killing Frost**[1]
1976	144	225	249	310	272
1977	153	215	234	290	285
1978	1135	195	337	297	312
1979	134	206	2333	305	312
1980	132	202	237	315	312
1981	145	216	239	302	296
1982	163	222	250	310	293
1983	156	216	243	303	312
1984	150	211	233	-------[2]	
1985	149	205	233	317	312
1986	171	212	232	363	286
1987	156	218	243	323	323
1988	144	213	234	315	312
1989	165	236	251	-------[2]	
1990	138	207	235	317	317
Mean	149	213	245	313	303

[1] Killing frost occurred on/or after day 312 (30 year average first frost).
[2] Did not harvest seed cotton.

Table 2. Mean damage of squares and small bolls in untreated cotton, value of crop in treated and untreated cotton and yields (Kg. Lint/ha) of treated and untreated cotton. Chickasha, OK. 1976-1990.

		Yields		Value of Crop ($)	
Year	Damaged (%)	Untreated	Treated	Untreated	Treated
1976	8.7	597.4	697.49	641.18	565.51
1977	19.3	698.29	614.51	741.05	508.36
1978	8.6	652.31	820.85	695.54	637.64
1979	9.9	850.79	884.76	892.03	750.91
1980	11.0	750.99	857.86	793.23	699.28
1981	10.3	610.82	741.23	654.46	633.82
1982	12.4	387.67	686.28	433.54	579.41
1983	11.0	654.56	704.22	697.76	572.18
1984	5.4	--------[1]	--------[1]		
1985	4.6	359.63	357.72	405.79	279.14
1986	1.8	707.26	770.38	749.93	662.68
1987	11.4	855.28	809.63	896.47	701.54
1988	12.8	682.59	836.54	725.3	728.18
1989	15.8	--------[1]	--------[1]		
1990	7.1	591.76	581.99	635.59	501.17
Mean	10.0	518	567	689.37	601.52

[1] Did not harvest seed cotton.

[2] Determined by calculating lint yield at $0.99 kg/ha---$25/application/ha and cost of application (x number of applications).

Table 3. Efficacy of certain insecticides against larval feeding damage to squares and small bolls by bollworm/tobacco budworm. Chickasha, OK. 1976-1987.

Year	Rate (kg (A.I.)/ha	Percentage Control	Percentage Increase of Yields
	Fenvalerate		
1976	0.112	68	21
1977	0.224	77	0
1978	0.112	77	33
1982	0.112	81	6
1983	0.112	69	0
1984	0.112	78	---------[1]
1985	0.112	59	0
1986	0.112	72	0
1987	0.112	56	0
Mean		71	8
	Esfenvalerate		
1985	0.014	41	0
	0.028	66	0
1986	0.033	61	7
	0.04	78	0
Mean		62	2
	Permethrin		
1976	0.112	74	16
1977	0.224	60	15
1979	0.112	46	0
1980	0.112	69	0
1981	0.112	69	11
1987	0.112	57	9
1988	0.112	30	19
Mean		58	10
	Cypermethrin		
1980	0.033	87	0
	0.056	90	21
	0.067	91	5
	0.134	89	21
1981	0.044	68	29
	0.067	74	42
	0.08	79	24
1983	0.044	59	12
1984	0.044	83	-------[-2]
1985	0.067	20	8
1987	0.044	44	0
1988	0.067	82	7
Mean		72	15
	Thiodicarb		
1976	0.56	78	0
1977	0.12	78	23
1978	0.042	81	26
1983	0.042	81	26
1985	0.67	52	0
1988	0.74	52	0
1989	0.67	70	0
1990	0.67	611	0
Mean		69	9
	Cyfluthrin		
1982	0.044	82	38
1983	0.028	70	0
1984	0.042	74	0
1986	0.028	78	5
1988	0.028	65	12
1989	0.028	68	0
1990	0.028	66	0
Mean		72	8

[1] Based on percentage of damaged squares and small bolls and increase in yields in untreated.
[2] Unable to determine.

Table 4. Efficacy of 34 mixtures of insecticides against bollworm/tobacco budworm and yields of cotton. Chickasha, OK. 1976-1990.

Year	Insecticides	Rate Kg (A.I.)/ha	Percentage Control	Percentage Increase of Yields
1976	Toxaphene + Methyl Parathion	2.24 + 1.12	49	21
	Chlordimeform +Profenofos	0.14 + 0.84	62	0
1977	Toxaphene + Methyl Parathion + EPN	0.89 + 0.44 + 0.24	58	0
	Methyl Parathion + Chlorpyrofos	1.12 + 0.56	69	0
	Methyl Parathion + Thiodicarb	0.56 + 0.336	75	12
1978	Toxaphene + Methyl Parathion	1.12 + 1.12	66	0
1979	Endrin + Methyl Parathion +Sulprofos	1.12 +1.12 +1.112	71	0
	Methyl Parathion + EPN + Methomyl	0.56 + 0.56 + 0.14	42	5
	Chlordimeform + EPN	0.14 + 1.4	64	10
	Chlordimeform + EPN + Methyl Parathion	0.14 + 1.4 + 0.84	61	0
1981	EPN + Methyl Parathion	1.12 + 1.12	25	0
	Chlordimeform + Methomyl	0.14 + 0.14	76	0
	Chlordimeform + Fenvalerate	0.14 + 0.112	73	23
1984	Chlordimeform + Cyfluthrin	0.14 + 0.028	85	----------[1]
1985	Chlordimeform + Cyfluthrin	0.14 +0.028	67	0
	Cyfluthrin + Sulprofos	0.028 + 0.56	67	0
1986	Chlordimeform + Cyfluthrin	0.14 + 0.067	100	16
1987	Chlordimeform + Cyfluthrin	0.14 + 0.044	73	0
	Chlordimeform + Thiodicarb + Profenofos	0.14 + 0.14 + 0.56	75	0
	Chlordimeform + Thiodicarb	0.14 + 0.56	31	1
	Cyfluthrin + Sulprofos	0.14 + 0.56	79	0
	Thiodicarb + Esfenvalerate	0.14 + 0.036	56	7
	Cypermethrin + Profenofos	0.044 + 0.14	42	0
1988	Methyl Parathion + Endosulfan	0.168 + 0.84	59	22
1989	Amitraz + Thiodicarb	0.14 + 0.67	84	----------[1]
	Thiodicarb + Cyfluthrin	0.14 + 0.028	75	----------[1]
1990	Amitraz + Profenofos	0.14 + 0.56	61	0
	Amitraz + Thiodicarb	0.028 + 0.14	38	1
	Profenofos + Thiodicarb	0.14+ 0.67	45	0
	Amitraz + Cyfluthrin	0.14 + 0.028	58	0
	Profenofos + Cyfluthrin	0.14 + 0.028	53	0
	Thiodicarb + Cyfluthrin	0.14 + 0.028	63	0
	Thiodicarb + *Bacillus thuringiensis*	0.14 + 709.8 ml	66	7
	Amitraz + *Bacillus thuringiensis*	0.14 +709.8 ml	42	0
Mean			62	4

[1]Unable to determine.