IMPACT OF A MORE INTENSIVE INSECT PEST INFESTATION LEVEL ON COTTON PRODUCTION: TEXAS HIGH PLAINS

Sharif M. Masud, Ronald D. Lacewell, John R. Stoll, J. Knox Walker, James F. Leser, and Christine Sellar

Abstract

This study evaluated implications of increased bollworm problems in a 20-county area of the Texas High Plains relative to cotton yields and economic impact. Results did not indicate a serious effect of bollworms upon lint yield when insecticides were used for control. However, estimated annual reduction in farmer profit due to the bollworm for 1979-81 was over $30 million. Yields were estimated to decline about 300,000 bales without insecticide use and about 30,000 bales with insecticide use. This decline suggests potentially serious implications for the comparative economic position of cotton in this region if insecticide resistance were to develop among insect pests.

Key words: cotton, bollworm infestation, farmer survey, yield response model.

Prior to 1975, cotton production on the Texas High Plains was relatively free of major insect pests. Damaging cotton bollworm *Heliothis zea* [Boddie] infestations on significant acreages occurred only at about 6-year intervals. Thrips *Frankliniella* spp. and cotton fleahopper *Pseudatomoscelis seriatus* [Reuter] infestations were not important in terms of intensity, distribution, or frequency of occurrence. Also, except for the early sixties (1963-64), beet armyworms *Spodoptera exigua* [Glover] infestations were minor. As a result of this relatively insect-free environment, cotton in the Texas High Plains was typically characterized by a low cost of production with limited introduction of insecticides into the environment.

Since 1975, bollworm infestations in cotton have become a major problem in the region. In 1980, about 1.5 million acres were affected with bollworms (Leser). Costs of production were affected and serious questions were raised about economic advantages of producing cotton in the region. Heavy bollworm infestations also caused a relatively large increase in quantities of insecticides introduced into the environment. At present there is no evidence of insecticide resistance by bollworms in the region. However, resistance of the boll weevil to chlorinated hydrocarbon insecticides was reported by Roussel and Clower in Louisiana in 1955, and by Walker et al. in Texas in 1956. Resistance of the bollworm and tobacco budworm to insecticides was reported by Adkisson et al. and by Collins et al. in the Lower Rio Grande Valley of Texas. Typically, with increasing insect resistance to insecticides, farmers tend to increase the number of insecticide applications and rates. This tends to worsen the problem.

There are several factors which may be interacting to contribute to the increased bollworm problem on the Texas High Plains.

Sharif M. Masud, Ronald D. Lacewell, and John R. Stoll are respectively visiting Assistant Professor, Professor, and Assistant Professor in the Department of Agricultural Economics; J. Knox Walker is Professor in the Department of Entomology; James R. Leser is Area Entomologist in the Texas Agricultural Extension Service; and Christine Sellar is former Post Doctorate Reseacher in the Department of Agricultural Economics, Texas A&M University.

Technical Article 20135 of the Texas Agricultural Experiment Station.

This paper is based on a cooperative study between the Texas Agricultural Experiment Station and Texas Agricultural Extention Service. The research was supported in part by the U.S. Department of Agriculture through a grant (Cooperative Agreement No. 82-CSRS-2-100) to Texas A&M University. The findings, opinions, and recommendations expressed herein are those of the authors and not necessarily those of the U.S. Department of Agriculture. Mention of a trademark or proprietary product does not constitute a guarantee or a warranty of the product by the Texas Agricultural Experiment Station nor does it imply its approval to the exclusion of other products that also may be suitable.

The authors wish to express their appreciation to the anonymous reviewers of the *Journal* who did excellent work in providing constructive comments for significantly improving the work and the manuscript.

The cropping system in this area has undergone extensive changes with large shifts in acreage of the major field crops. A ten-fold increase in corn acreage during the 1969-1981 period provided an early host plant for a bollworm population buildup prior to cotton reaching the blooming stage. For the same period, a 50 percent reduction in grain sorghum acreage may have removed a potential source of beneficial arthropods. Presently, sorghum acreage is so limited that it is doubtful whether beneficial insects produced with this crop are having much impact on minimizing late season pest problems in cotton.

In areas where corn had replaced grain sorghum, cotton acreage more than doubled due to favorable growing and pricing conditions. This additional cotton acreage is in an area where bollworm damage risks would be highest because of its proximity to corn, the shortness of the growing season, and large irrigated acreages. Other important factors which may have a role in increasing bollworm outbreaks include: (1) hot dry weather for several years, (2) increased pesticide use in other crops, (3) decreased beneficial arthropods activity, and (4) attempts to harvest a late crop of bolls on cotton (Leser).

The purpose of this study was to estimate the economic impact of the increased pressure of bollworms on cotton output, farmer profit, and insecticide use for the Texas High Plains. The study has economic implications for farmers and scientists concerning the appraisal of bollworm problems and future production and research decisions.

STUDY AREA

The study area included 20 counties of the Southern High Plains of Texas and is characterized by medium-to-fine textured soils. These soils are capable of high yields, but their productivity is limited by low rainfall, high winds, temperature extremes, and a short growing season. Average annual rainfall ranges from 14 to 21 inches, with the growing season averaging from 180 to 220 days. Water for irrigation comes from the Ogallala aquifer.

The High Plains region has 34 percent of the total cropland and approximately 70 percent of the irrigated cropland in Texas. The region also produces about 78 percent of the fed cattle in Texas (Texas Department of Water Resources). Cotton, corn, grain sorghum, and forage sorghum are the most common annual crops grown in the area. During the period 1970-1981, planted acreages for dryland and irrigated cotton for the region's 20 counties averaged 1.3 million and 1.7 million, respectively. During the same period, the region's yield per planted acre of dryland and irrigated cotton averaged 243 and 378 pounds, respectively. Cash receipts from farm marketing for crops were about $1.2 billion in 1982. The corresponding figure for livestock and livestock products was about $360 million (Texas Crop and Livestock Reporting Service, 1983).

METHODS

This study was designed to evaluate implications of increased bollworm infestation levels on the southern High Plains of Texas relative to cotton yields and economic impact.

Farmer Survey

The study was based on responses from cotton producers in a 20-county region. A sample of 30 representative cotton farmers per county was selected and mailed a questionnaire by the county agricultural agent of the Texas Agricultural Extension Service. The questionnaire was designed by a researcher at Texas A & M University in consultation with Extension Service personnel. The initial mailing contained 600 questionnaires of which 297 were completed and returned. This constituted a 49 percent response rate.

The total questionnaire basically included questions: (1) to characterize the bollworm problem and other insect pest infestations, (2) related to general crop production, (3) concerning production during the 1979-1981 period, and (4) concerning personal information. The survey covered the 1979-1981 cotton production years.

A summary of the responses of cotton producers to each question was provided in a preliminary report by Sellar et al. The present study includes detailed economic and statistical analysis with grower responses separated between dryland and irrigated cotton production and by geographical area. The analysis required additional data on dryland and irrigated cotton budgets, monthly rainfall, and first fall frost dates.

Cotton Yield Response Model

To estimate the yield and economic damage attributable to bollworms on cotton, dryland and irrigated cotton yield response models were specified. Dryland cotton yields were assumed to be influenced by bollworm infestation levels, rainfall (timing and amount), number of frost free days after planting, corn acreage, and number of times cotton fields were treated by insecticides. Similarly, irrigated cotton yields were assumed to be influenced, in addition to all of the variables specified previously, by the number of irrigation applications (pre-plant plus number of post-plant applications). Several functional forms were considered, including second degree polynomial and log-linear functions. Preliminary regression results for both yield response models showed that the data were characterized by autocorrelated residuals. For this reason, a first degree polynomial model for dryland cotton and first degree polynomial model with linear and quadratic rainfall variables for irrigated cotton were estimated using autoregressive procedures and assuming the error term for each model to be an autoregressive process of the order NLAG=1 (SAS/ETS User's Guide).

A major source of data for estimating the models was the information provided by cotton growers in the survey. Some 70 percent of the cotton farmers in the region indicated that the bollworm is the insect pest which causes the greatest damage to the cotton crop during an average year. Bollworm infestations were rated by producers as light, moderate, or heavy during the 1979-1981 period.

Monthly rainfall records by county for the period 1979-1981 were obtained from the U.S. Department of Commerce. Records for first fall frost date by county for 1979-1981 were taken from published sources (U.S. Department of Commerce). Planting dates for dryland and irrigated cotton were obtained from farmers for each year from the survey. The difference between planting date and first frost day was the estimate of frost free growing days applicable to each grower in each year.

The importance of corn has increased dramatically since 1970. In 1976-77, corn acreage was near 1.4 million acres declining to about .6 million acres in 1982 (Texas Crop and Livestock Reporting Service, 1983). Corn has been discussed as a possible factor contributing to increased bollworm problems in cotton since corn provides an ideal, early host plant for bollworm population buildup prior to cotton entering the blooming stage. In this study, corn acreage was used as a dummy variable for both the dryland and irrigated cotton yield functions, being a 0 for those producers who did not plant corn and a 1 for producers who did.

Insecticides such as Pounce®, Ambush®, Pydrin®, and Dipel® are applied to control bollworm infestations in cotton. The insecticide variable was included in the model based on the number of times a field was treated. One insecticide treatment included about 0.125 pounds of active ingredient (A.I.) per acre.

Observations on pre-plant and post-plant irrigation were recorded from the farmer survey. The pre-plant irrigation was included as a dummy variable with 0 for application and 1 for non-application. The post-plant irrigation was related to the number of times cotton fields were irrigated. Yield data by year for both dryland and irrigated cotton were provided by cotton growers in the survey.

Analyses were performed using several alternative specifications for the dryland and irrigated yield response models, Table 1. Of the model specifications, the coefficient for the yield effect due to bollworm infestation was negative and ranged between 0 and −13 for dryland cotton and between −23 and −40 for irrigated cotton. Similarly, the coefficient for the total insect treatment was positive and ranged between 42 and 51 for dryland cotton and 49 to 57 for irrigated cotton. The method of using many model specifications in regression analysis to identify the impact of a variable or policy such as the bollworm infestation level or total insect treatment is discussed by Ziemer. Basically, the objective is to concentrate on a single variable of interest without being overly concerned with other variables and not relying on their estimated coefficients. It is important that the policy variable be constant in sign and the nearer the upper and lower bounds of parameters over many specifications, the more confident one can be about inferences made from results. A recent study by Masud et al., 1985b, used this method to evaluate economic implications of a regional uniform planting date (UPD) cotton production sys-

TABLE 1. ESTIMATES OF THE AUTOGRESSIVE PARAMETERS OF DRYLAND AND IRRIGATED COTTON YIELD RESPONSE MODELS, TEXAS HIGH PLAINS, 1979-1981

Item[a]	Model 1-Dryland		Model 1-Irrigated	
	Coefficient	Standard-error	Coefficient	Standard-error
Constant	8.894	50.216	-289.379[b]	59.163
BWINFST	-12.269[b]	5.038	-24.751[b]	5.688
RAINONDL	23.464[b]	4.172	127.558[b]	18.274
$(RAINONDL)^2$	—	—	-17.841[b]	2.952
RAINFMA	29.589[b]	2.451	115.398[b]	16.721
$(RAINFMA)^2$	—	—	-14.523[b]	2.483
FFDAPLG	0.968[b]	0.380	2.816[b]	0.406
CORNAC	-164.543[b]	23.627	-61.997[b]	14.826
INSECT	51.253[b]	8.116	55.515[b]	5.470
PREPLIRR	—	—	-30.769[c]	25.012
POSTPLIRR	—	—	48.887[b]	6.364
R^2	0.265		0.356	
MSE	3241.192		3372.004	
N	.153		.153	

[a] Variable definitions are:
BWINFST = bollworm infestation levels with 1=light, 2=medium, and 3=heavy,
RAINONDL = inches of total rainfall in October, November, and December lagged one year,
RAINFMA = inches of total rainfall in February, March, and April,
FFDAPLG = number of frost free days after planting by growers,
CORNAC = dummy variable for corn acreages on the farm (1=yes, 0-no),
INSECT = total insect treatments (number of times), bollworm and other,
PREPLIRR = dummy variable for pre-plant irrigation (0=yes, 1-no), and
POSTPLIRR = post-plant irrigation (number of times).
[b] Indicates significance at the .01 level.
[c] Indicates significance at the .05 level.

tem on the Texas Rolling Plains and mainly concentrated on the UPD variable.

For estimation, data provided from the survey (farmer data) included: (1) bollworm infestation level, (2) corn acreage on farm, and (3) number of insect treatments, preplant irrigation, and post-plant irrigation. Frost free growing days were calculated for each year by farmer as the time from the farmer's planting date to the first frost date in the county. County data used for all farmer surveys in the county included (1) rainfall in October, November, and December lagged one year and (2) rainfall in February, March, and April. About 27 percent of the variation in dryland cotton yield and 36 percent of the variation in irrigated cotton yield on the Texas High Plains was explained by the two yield models, Table 1. Other variables such as blowing sand, hail, etc., which are important in explaining yields in the region were not included because of a lack of data. However, using the variables that are included in the model provides defensible dryland and irrigated cotton yield functions for the Texas High Plains. All estimated coefficients have signs which conform to expectations.

The estimated model indicated yield is influenced by several factors. The bollworm infestation is estimated to decrease cotton yields, while insecticide use increases yield. For dryland cotton, a 12-pound yield decrease for light infestation, 24-pound for moderate infestation, and 36-pound for heavy infestation per acre were estimated. The corresponding yield decline values for irrigated cotton were 25, 50, and 75 pounds per acre for light, moderate, and heavy bollworm infestations, respectively.

The estimated insecticide treatment coefficient suggest that farmers harvest an additional 51 pounds of dryland cotton and 56 pounds of irrigated cotton per insecticide application per acre relative to those farmers not applying insecticide. The average number of applications in the study area was less than one. The implication is that cotton farmers obtain effective bollworm control via insecticides but do not require them every year on each acre. The average insecticide material and application cost is assumed to be $9.50 per acre for the study region (Extension Economists-Management). The estimated pre-plant irrigation coefficient indicates that per acre yields were reduced about 30 pounds when a pre-plant irrigation was not applied in the field. Each post-plant irrigation of cotton fields was estimated to increase yield by about 49 pounds per acre.

The estimated coefficients for other remaining variables, such as rainfall and frost free days after planting, in both the dryland and irrigated cotton yield models suggested that lint yields are typically increased for every day that is frost free after planting. The equation also emphasizes the importance of winter and early spring rainfall in increasing dryland and irrigated cotton yields.

Farmer Impact

Published crop enterprise budgets for dryland and irrigated cotton production on the Texas High Plains provided the base data for economic evaluation (Extension Economists-Management). The crop budgets indicate the level of input use and expected production or yield. These crop budgets were modified for alternative levels of bollworm infestation, based on farmer survey data and results of the yield response models, to estimate per acre economic implications for dryland and irrigated cotton. The major variables affected by bollworm infestation were yield and harvest, insecticide, and labor costs. By comparing the alternative crop budgets developed for alternative levels of bollworm infestation, changes in farmer profit were estimated.

Aggregate Economic Impact

The estimated per acre yield and producer cost effects of alternative levels of bollworm infestation were aggregated across all cotton acres by year for dryland and irrigation production to estimate the total potential (no pesticide use) and actual (best pesticide estimates) yield loss, and grower profit change. However, it was assumed that bollworm infestations in the Texas High Plains cover such a small region as compared to the total cotton producing areas that any change in cotton output was sufficiently small so as to not affect market prices. Data on dryland and irrigated cotton acreages by year were available from the Texas Crop and Livestock Reporting Service. In addition, data on percent of acreages and insecticide applications for dryland and irrigated cotton with alternative levels of bollworm infestation were provided by cotton farmers in the survey. Total harvested acres were assigned alternative levels of bollworm infestation using the percentages developed from grower responses. The adjustment factors and methods used in estimating the aggregated economic impact by dryland and irrigated cotton acreages and insecticide treatment for each year during the 1979-1981 period are discussed as follows.

(1) Yield loss for alternative levels of bollworm infestation is evaluated in terms of actual and potential loss.

(i) Potential production loss (no insecticide use) may be represented as:

$$PYL_{ijk} = (\hat{b}_{i1} \bullet BWINFST_{ijk}) \bullet ACRES_{ijk},$$

where:

PYL_{ijk} = estimated pounds of potential cotton lint loss attributable to bollworms assuming no insecticide (bollworm control) by dryland or irrigated production (i), level of bollworm infestation (j), and year (k),

$\hat{b}_{i1}$ = estimated per acre lint yield reduction associated with bollworm infestation on dryland (−12.269) or irrigated (−24.751) cropland,

$BWINFST_{ijk}$ = level of bollworm infestation (1,2, or 3) by dryland or irrigated, and year, and

$ACRES_{ijk}$ = total acres of dryland and irrigated (i), level of bollworm infestation (j), and year (k) established by using the proportion of survey acres in each category against published total dryland and irrigated acres harvested each year.

The estimate of PYL_{ijk} provides the basic information for summing potential cotton lint losses due to bollworms for dryland and/or irrigated production by level of infestation or across all bollworm infestation levels by or across years. The PYL estimate with no bollworm control measures by farmers is an upper estimate of potential lint loss.

(ii) Estimated production loss may be represented as:

$$YL_{ijk} = [(\hat{b}_{i1} \bullet BWINFST_{ijk} - (\hat{b}_{i6} \bullet INSECT_{ijk})] \bullet ACRES_{ijk},$$

where:

YL_{ijk} = estimated pounds of actual cotton lint loss attributable to bollworms given levels of bollworm control used on dryland or irrigated cotton acres, level of bollworm infestation, and year,

$\hat{b}_{i6}$ = estimated per acre cotton lint yield impact due to each insecticide application by dryland (51.253) and irrigated (55.515) cotton production, and

$INSECT_{ijk}$ = number of insecticide applications by dryland or irrigated cotton production, by level of bollworm infestation and year, calculated from the responses on the growers survey applicable to each category.

As previously discussed, YL_{ijk} may be summed to estimate the actual cotton lint reduction for 1979-1981 by dryland and/or irrigated production and by or across level of bollworm infestation.

(2) Quantity of insecticide (A. I.) applied may be represented as:

$$QAI_{ijk} = ACRES_{ijk} \bullet (AI \bullet INSECT_{ijk}),$$

where:

QAI_{ijk} = pounds of active ingredient of insecticide applied for bollworm control by dryland or irrigated production, level of bollworm infestation, and year, and

AI = average pounds of active ingredient of insecticide per acre.

(3) Producer net return reduction may be represented as:

$$TNR_{ijk} = (NR_i - NRBW_{ij}) \bullet ACRES_{ijk},$$

where:

TNR_{ijk} = estimated reduction in producer net returns by dryland or irrigated production, level of bollworm infestation, and year,

NR_i = expected producer net returns per acre in the absence of bollworms by dryland and irrigated production, and

$NRBW_{ij}$ = expected producer net returns per acre under dryland or irrigated production at alternative levels of bollworm infestation. This was calculated by modifying cotton enterprise budgets for changes in yield, insecticide cost, and harvesting, gin, bag, and ties costs.

The values of PYL_{ijk}, YL_{ijk}, QAI_{ijk}, and TNR_{ijk} provide the basis for estimating potential lint loss due to bollworms, actual lint loss, amount of insecticide used, and reduction in producers' net returns for 1979-1981.

RESULTS

Results are presented relative to the autoregressive analysis which provided estimates of yield decline for dryland and irrigated cotton due to bollworm infestations. This was used to establish the effect on farmer profits in conjunction with the change in insecticide use. Lastly, the implication for the region was developed for each year 1979-1981, based on acres in each bollworm infestation level classification.

Farmer Impact

The cotton yield response models demonstrate the effect of bollworm infestations and insecticide applications on dryland and irrigated cotton yields for the Texas High Plains. However, a critical issue is whether costs and returns of cotton producers were affected. A budgeting analysis was used to examine the per acre implications for dryland and irrigated cotton with typical production situations and alternative levels of bollworm infestations in the region.

Analysis of dryland and irrigated cotton enterprise budgets in the region suggested that bollworm infestations resulted in lower returns per acre as compared to the respective typical production situation, Table 2. Returns over variable costs for dryland cotton with light, moderate, and heavy bollworm infestations were estimated to be reduced by \$4.48, \$7.62, and \$8.82 per acre, respectively, as compared to the dryland cotton budget with no infestation. Similarly, returns over variable costs for irrigated cotton with light, moderate, and heavy bollworm infestations were reduced by \$7.68, \$8.75, and \$13.45 per acre, respectively, as compared to the no infestation (pre-bollworm), irrigated cotton budget, Table 2. These estimates are measures of direct farmer loss due to the bollworm infestation and subsequent insecticide application to control the bollworm.

TABLE 2. PER ACRE IMPACT OF DRYLAND AND IRRIGATED COTTON WITH TYPICAL PRODUCTION (PRE-BOLLWORM) AND ALTERNATIVE BOLLWORM INFESTATION LEVELS, TEXAS HIGH PLAINS, 1979-81

Water practice	Bollworm infestation level	Per acre returns over variable costs	Reduction in profits per acre[a]
		($/Acre)	($/Acre)
Dryland	None[b]	52.66	N.A.
Dryland	Light	48.18	4.48
Dryland	Moderate	45.04	7.62
Dryland	Heavy	43.84	8.82
Irrigated	None[b]	48.80	N.A.
Irrigated	Light	41.12	7.68
Irrigated	Moderate	40.05	8.75
Irrigated	Heavy	35.35	13.45

[a] Difference in per acre returns over variable cost between typical or pre-bollworm and alternative bollworm infestation levels.

[b] Assumes no bollworm infestations, insecticide use, or insecticide costs.

Per acre reductions in profit for irrigated farmers with alternative bollworm infestations are greater because of higher insecticide costs as compared to dryland farmers with similar bollworm infestations.

Insecticide application, quantity, frequency, and costs for dryland and irrigated cotton with alternative levels of bollworm infestation are presented in Table 3. In general, the estimated quantities of insecticide applied per acre for irrigated cotton with light, moderate, and heavy bollworm infestation are higher as compared to corresponding infestation levels for dryland cotton. Consequently, per acre costs of bollworm control for irrigated cotton with light, moderate, and heavy bollworm infestations are higher by $1.66, $6.15, and $4.63, respectively, as compared to the corresponding infestations for dryland cotton, Table 3.

Aggregated Economic Impact

Per acre insecticide applications were aggregated across acres in each bollworm infestation classification for dryland and irrigated cotton to estimate total pounds of insecticide applied in the region for the years 1979-1981. The analysis indicated that irrigated cotton producers applied about twice as much insecticide as dryland cotton producers in each year during this period (Masud et al., 1985a). For example, it was estimated that cotton producers who irrigated applied an average annual quantity of 220 thousand lb./AI of insecticide as compared to 108.2 thousand lb./AI for dryland farmers during the 1979-1981 period. Aggregating dryland and irrigated insecticide applications, it was estimated that 262.4 thousand lb./AI in 1979 as compared to about 363.9 thousand lb./AI in 1980 and 358.3 thousand lb./AI in 1981 were used. Thus, an estimate of average annual quantity of insecticide use was about 328.2 thousand lb./AI in the region, Table 4.

When insecticides were used for bollworm control, the estimated dryland and irrigated cotton yield loss was greatly reduced as compared to the yield loss when no insecticides were used during this period. For dryland cotton production, estimated lint losses due to bollworms were 19,437 bales, 93,661 bales, and 109,723 bales, respectively. The corresponding values of lint production loss for irrigated cotton were 14,699 bales, 12,899 bales, and 8,932 bales during the 1979-1981 period as compared to the potential (no pes-

TABLE 3. PER ACRE COMPARISON OF INSECTICIDE USE AND COSTS FOR DRYLAND AND IRRIGATED COTTON PRODUCTION WITH ALTERNATIVE BOLLWORM INFESTATION LEVELS, TEXAS HIGH PLAINS, 1979-81

Water practice and bollworm infestation	Insecticide use		Insecticide costs	Insecticide application	Total costs
	Amount	Application			
	(lb./AI)	(no.)	($/acre)	($/acre)	($/acre)
Dryland:					
Light	0.013	0.1049	0.68	0.31	0.99
Moderate	0.034	0.2753	1.77	0.83	2.60
Heavy	0.116	0.9287	6.03	2.79	8.82
Irrigated:					
Light	0.035	0.2771	1.82	0.83	2.65
Moderate	0.115	0.9237	5.98	2.77	8.75
Heavy	0.117	1.4181	9.20	4.25	13.45

TABLE 4. AGGREGATE EVALUATION OF IMPACT OF INCREASED BOLLWORM PRESSURE ON COTTON, TEXAS HIGH PLAINS, 1979-81

Item	Unit	Aggregate evaluation by year		
		1979	1980	1981
Insecticide use	1,000 lb./AI	262.4	363.9	358.3
Lint reduction:				
Actual	bales	34,136	25,566	35,589
No pesticide[a]	bales	249,861	322,922	334,685
Profit loss[b]	million $	31.7	33.3	35.1

[a] This value represents an upper limit of potential lint reduction due to greater bollworm pressure assuming producers did not apply any control.
[b] Based on actual lint reduction estimated when insecticide was applied.

ticide use) loss of 165,225 bales, 229,261 bales, and 224,962 bales, respectively. Aggregating dryland and irrigated acreages, estimated lint loss was 34,136 bales as compared to the potential loss of 249,861 bales if no insecticide had been used in 1979, Table 4. Similarly, estimated yield losses were substantially reduced in 1980 and 1981 as compared to the pontential (no pesticide) yield losses. Finally, the estimated average annual production loss was 31,764 bales as compared to the estimated average annual production loss of 302,489 bales if insecticides had not been used during the 1979-1981 period.

The no insecticide use (no bollworm control) scenarios resulted in large yield and consequently profit impacts, possibly large enough to affect cropping patterns and lint price. Cropping pattern or lint price effects were not considered and thus the results represent an upper limit on potential impacts of the bollworm.

This analysis illustrates the severity of the bollworm problem and the necessity of applying insecticide to control bollworms to reduce yield losses in the region. However, increased insecticide use also increases production costs and results in lower profits for cotton producers than would occur without bollworm infestations. Aggregate reduction in profits to dryland and irrigated cotton producers in the region were estimated for the 1979-1981 period. The aggregate reduction in profit for dryland cotton was estimated to be $11.0 million in 1979, $11.3 million in 1980, and $14.2 million in 1981. The corresponding values for irrigated cotton were $20.7 million, $22.0 million, and $20.9 million, respectively. The aggregate dryland and irrigated profit losses in the region were estimated at $31.7 million in 1979, $33.3 million in 1980, and $35.1 million in 1981, Table 4. By simply averaging across years, the region's cotton farmers experienced an average annual reduction in profit estimated at $33.4 million per year for the 1979-1981 period.

SUMMARY AND CONCLUSIONS

This study examined the economic impact of bollworms upon cotton production in a 20-county area of the Texas High Plains during the 1979-1981 period. Dryland and irrigated cotton yield response models were estimated using autoregressive procedures with data from a farmer survey and secondary sources. The estimated models were then used to establish per acre effects for estimating regional economic impacts attributable to bollworm infestation.

Analyses did not indicate a serious effect of bollworms upon lint yield when insecticides were used for control. However, consideration of the estimated yield impacts when no insecticides were used indicates that if bollworm resistance to insecticides were to develop, the temporal implications could be dramatic. There were no indications of such a development but if the bollworm were to develop greater resistance to insecticides, higher yield losses would be incurred and insecticide control costs could be increased. This could seriously affect the comparative economic position of cotton in this region as compared to other cotton production regions in the United States and the world. As has been shown in the present study, bollworm infestations have reduced regional cotton production profits by approximately $33.4 million per year from what they would have been prior to bollworm infestation. This figure would be increased if insecticide resistance were to occur.

REFERENCES

Adkisson, Perry L., George A. Niles, J. Knox Walker, Luther S. Bird, and Helen B. Scott. "Controlling Cotton Insect Pests: A New System." *Science*, 216(1982): 19-22.

Collins, G. S., R. D. Lacewell, and J. Norman. "Economic Implications of Alternative Cotton Production Practices: Texas Lower Rio Grande Valley." *So. J. Agr. Econ.*, 11,1(1979): 79-82.

Extension Economists-Management. "Texas Crop Budgets." Texas Agricultural Extension Service, Texas A & M University, 1984.

Leser, J. F., "High Plains Cotton Pests Now Big Economic Problem." Southwest Farm Press; March 3 and March 19, 1981 (as reported by Wayne Board, Associate Editor).

Masud, S. M., R. D. Lacewell, J. R. Stoll, J. K. Walker, and J. F. Leser. "Economic Impact of Increased Bollworm Pressure on Cotton: Texas High Plains." Texas Agricultural Experiment Station Publication, MP-1590, September 1985a.

Masud, S. M., R. D. Lacewell, E. P. Boring, III, and T. W. Fuchs. "Economic Implications of a Regional Uniform Planting Date Cotton Production System: Texas Rolling Plains." *J. Econ. Entomol.*, 78(1985b): 535-41.

Roussel, J. S. and D. Clower. "Resistance to the Chlorinated Hydrocarbon Insecticides in the Boll Weevil." Louisiana Agricultural Experiment Station Circular 41, 1958.

SAS/ETS User's Guide, Econometric and Time-Series Library, SAS Institute, Inc.; Cary, North Carolina; 1980 Edition.

Sellar, C., J. R. Stoll, R. D. Lacewell, J. K. Walker, J. F. Leser, and R. S. Ziemer. "Texas High Plains Bollworm Survey: A General Summary of Results." Department of Agricultural Economics, Texas A & M University, Departmental Technical Report, DTR-82-2; December, 1982.

Texas Crop and Livestock Reporting Service. Texas Agricultural Cash Receipts Statistics, U.S. Department of Agriculture, Austin, 1983, p. 44.

Texas Crop and Livestock Reporting Service. Texas Cotton Statistics, U.S. Department of Agriculture, Austin, 1970-1981.

Texas Department of Water Resources. "Fact Sheet on the Economy of the Texas High Plains." Planning and Development Division, Pamphlet; May, 1981.

U.S. Department Commerce. "Climatological Data, Texas." National Climatic Center, Asheville, North Carolina, 1978-1981.

Walker, J. K., B. G. Hightower, R. L. Hanna, and D. F. Martin. "Boll Weevils Resistant Chlorinated Hydrocarbons." Texas Agricultural Experiment Station Progress Report Number 1902, 1959.

Ziemer, R. R. "Econometric Results: Believe it or Not?" *Land Econ.*, 60(1984): 122-7.