AN ECONOMIC ANALYSIS OF SELECTED

TECHNOLOGICAL DEVELOPMENTS IN

COTTON PRODUCTION

By

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CHAPTER I

INTRODUCTION

The cotton industry in Oklahoma, as most segments of the state's agricultural industry, is experiencing a rapid increase in the use of technology. During the last three decades cotton production has changed from animal power and hand labor to tractors and mechanization. Defoliants, desiccants, insecticides, and fertilizers have increased in use. New equipment and machines are constantly being introduced. As these changes occur, the farm manager has the problem of re-evaluating production techniques and deciding which technological developments will maximize attainment of his production goal(s). Farm managers must answer these questions because the cost-price squeeze, interregional competition, and interfiber competition are forcing Oklahoma cotton farmers to produce their product at lower per unit cost.

If Oklahoma farmers can quickly recognize and use those technological developments that decrease per unit costs of output (without decreasing output), they will gain an economic advantage until the industry has adjusted to the innovation. Likewise, farm managers who miscalculate and use unprofitable technology will be at disadvantage because the industry will be producing with lower per unit costs.

In summary, Oklahoma cotton producers have two specific decision problems:

(1) Which technological developments can profitably be used (i.e., how to produce), and

(2) To what degree should technological developments be used, (i.e., how much to produce).

To answer these questions, farmers need the following information:

(1) factor-product relationships (physical data),

(2) factor costs and product prices (economic data), and

(3) analytical techniques (ways of analyzing and choosing between alternatives).

This study is designed to provide such information.

Manufacturing firms and government agencies attempt to improve farmers' knowledge in these areas through research, experimentation, and pilot tests. Such efforts have improved man's knowledge of the requirements for decision making; thus, better estimates of the appropriate technological developments for the various goals can be made.

Previous Research

Considerable cotton production technology research has been done in Oklahoma. The usefulness of previous research in each of the areas required for decision making will now be considered.

Factor-Product Relationships

The Agricultural Engineering, Agronomy, and Entomology Departments at Oklahoma State University have conducted experiments designed to estimate factor-product relationships in Oklahoma cotton production. That is, experiments were designed to indicate crop yield responses to discrete levels of specified factor(s) and alternative levels of factors for given cotton production.

The results of these experiments are undoubtedly useful to farm managers. However, the task of providing information is not complete until the results of these experiments are stated in terms of economic outcomes or specific managerial goals or objectives. If a farmer has a physical goal, such as maximum yield, the results of present and past research in raw form are extremely helpful. However, if a farmer has an economic goal, such as maximum profits, then the usefulness of available information can be increased by stating the results of the experiments in monetary rather than physical terms.

Factor Costs and Cotton Prices

Costs for variable factors such as insecticides, fertilizer, seed, etc., are generally known at the time production plans are made. Machinery and labor costs vary among farmers. However, these costs can be estimated or custom (hiring) rates can be used. Walker, Jeffrey, and Maynard compiled the custom rates for areas in Oklahoma having similar agricultural characteristics.[1]

Government support prices and the price forecasting activities of the Agricultural Marketing Service lessen cotton price uncertainty to some degree. However, price uncertainty is a problem that does not lend itself well to present research techniques and has only been slightly

[1]Odell L. Waler, D. B. Jeffrey, and Cecil D. Maynard, "Oklahoma Custom Rates," Oklahoma State University Extension Service Leaflet L-50, 1960.

resolved. In this study, it is necessary to assume particular cotton prices; however, these prices are not to be regarded as predictions of future prices. Lagrone, Plaxico, and others conducted studies involving factor costs and cotton prices.[2]

Analytical Techniques

Walker, Wiggans, and Pogue conducted a study on fertilizer and seeding rates for spinach production.[3] Plaxico, Andrilenas and Pope performed an economic analysis of concentrate-roughage ratios for feeder cattle.[4] Lagrone, Back, and others have used budgeting in several

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[2]William F. Lagrone, Percy L. Strickland, Jr., and James S. Plaxico, "Resource Requirements, Costs, and Expected Returns; Alternative Crop and Livestock Enterprises; Sandy Soils of the Rolling Plains of Southwestern Oklahoma," Oklahoma State University Agricultural Experiment Station Processed Series P-369, February, 1961.

John W. Goodwin, James S. Plaxico, and William F. Lagrone, "Resource Requirements, Costs, and Expected Returns; Alternative Crop and Livestock Enterprises; Clay Soils of the Rolling Plains of Southwestern Oklahoma," Oklahoma State University Agricultural Experiment Station Processed Series P-357, September, 1960.

Larry J. Connor, James S. Plaxico, and William F. Lagrone, "Resource Requirements, Costs, and Expected Returns; Alternative Crop and Livestock Enterprises; Loam Soils of the Rolling Plains of Southwestern Oklahoma," Oklahoma State University Agricultural Experiment Station Processed Series P-368, February, 1961.

[3]Odell L. Walker, Samuel C. Wiggans, and Thomas F. Pogue, "An Economic Analysis of Fertilizer and Seeding Rates for Spinach Production in Eastern Oklahoma," Oklahoma State University Agricultural Experiment Station Bulletin B-596, June, 1962.

[4]James S. Plaxico, Paul Andrilenas, and L. S. Pope, "Economic Analysis of a Concentrate-Roughage Ratio Experiment," Oklahoma State University Agricultural Experiment Station Processed Series P-310, January, 1959.

studies. Analytical techniques used in the above studies are applicable to the problem of this thesis, but the products are different.

Objectives

The primary objective of this thesis is to increase the usefulness of technological research to cotton producers by making an economic analysis and evaluation of selected technological developments.

Secondary objectives are:

(1) To present the tools whereby farmers and researchers may evaluate forthcoming technological developments and to demonstrate the use of statistical, economic, and game theory techniques which may be applicable to other data.

(2) To make suggestions regarding design, method, or reporting of research which might increase its usefulness to farmers or other researchers.

Procedure

Many technological developments have been made during recent years, and space will not allow all of them to be discussed. Therefore, some of the major technological developments have been selected for treatment. Each chapter discusses one or more major technological developments. The same procedure is followed in each chapter. The organization of each chapter is as follows:

(1) The problem setting is described and needed information is specified.

(2) Available information is presented and discussed under (a) physical data, and (b) economic data headings.

The physical data used in this study were obtained from the Agricultural Engineering, Agronomy, and Entomology Departments at Oklahoma State University. In some instances speculation is made as to the influences that various factors such as weather had on the physical data. However, the author recognizes that physiology is not his principal field.

Assumptions about economic data used in each chapter are stated. Alternative assumptions and prices can be substituted for those used in this study. Throughout this study, the assumption is made that capital is available to purchase the technological developments being analyzed. That is, it is assumed that the farm manager either has or can borrow the necessary funds. The costs used include either an interest cost or an opportunity cost (value of capital in its best alternative use). These assumptions are made to permit each technological development to be analyzed independently of other farming operations.

(3) An analytical technique which utilizes the available information and indicates a solution to the problem is developed. The analytical technique which is needed is developed in each chapter; however, some general background information for all of the chapters will now be presented.

Analytical techniques are needed to guide the systematic consideration of pertinent information and the subsequent formulation of an optimal production strategy. The proper analytical or decision making technique designates the best means of achieving a desired result. The appropriate decision making technique depends on the degree of knowledge and the managerial goal. Thus, before these techniques are discussed, they will be classified according to the degree of knowledge and managerial goals.

Degrees of Knowledge

Knowledge situations can be regarded as a continuum of knowledge and any classification of such will be subjective. That is, different individuals with the same amount of information might classify their knowledge situations differently. The knowledge situations on the continuum of knowledge have two important characteristics which aid in their classification:

(a) Possible outcomes,

(b) The probabilities of the outcomes.

The degrees of knowledge in this thesis are classified on the basis of the foregoing characteristics into the following categories:

(a) Perfect knowledge represents one extreme of the continuum because the outcomes are known with absolute certainty. That is, the probability of the expected results being realized is known to be one. Perfect knowledge of the outcome of a particular production strategy in the real world does not exist; however, the manager's knowledge may be such that he acts as though it is perfect. This category of knowledge is useful for analytical and explanational purposes because of its simplicity.

(b) The risk situation is another classification of the degree of knowledge. In this situation, two or more known outcomes exist. The probabilities of each outcome are also known. These probabilities may have been determined statistically or subjectively.

(c) Uncertainty exists when the possible outcomes are known, but the probability of each outcome is unknown. It should be noted that the risk and uncertainty situations have certain things in common (some knowledge) and are sometimes combined into "imperfect knowledge."

(d) The no-knowledge situation is the other extreme of the knowledge continuum. This situation exists when possible outcomes and probabilities of the outcomes are unknown. This situation is not considered because the manager does not have enough information to make a rational decision. It is possible that the manager may obtain more information, i.e., the probability distribution and/or the possible outcomes may become known which would allow a decision to be made. However, when this event occurs, the manager's knowledge situation has changed to one of the previously discussed situations.

Managerial Goals

Two characteristics of managerial goals are generally accepted.

(a) Maximum utility for himself and his family is a probable goal of a farm manager.

(b) Utility is a function of several variables and net returns is one of the most important of these variables.

From these characteristics, it might be deduced that net returns are a rough measure of utility. This does not necessarily mean that maximum net returns indicates maximum utility. However, it does mean that some level of net returns is associated with maximum utility. Thus, in this thesis, a managerial goal is defined as a level of net returns causing or accompanying maximum utility. Several levels of net returns (managerial goals) will be discussed.

The three levels of net returns (managerial goals) considered are as follows:

(a) Maximize Net Returns Over Time. A farm manager might have this goal if he feels his tenure, equity position, family responsibilities, etc., are such that he can withstand the worst possible series of unfavorable outcomes. The manager using this goal must envision or know the probability distribution of outcomes and be willing to wait until the actual distribution conforms with the envisioned distribution. Thus, this goal is appropriate only for perfect knowledge and risk situations.

(b) Maximize Security Level In Each Time Period. The security level for any particular strategy is defined as the minimum possible level of net returns for that strategy. The security level for all strategies is the greatest (maximum) minimum level of net returns. A manager with this goal wants to use the best strategy against the worst that can happen. A farm manager with severely limiting resources, large family responsibilities, children in college, a large debt, or a dislike for chance taking might choose this goal. Since the manager only considers the possible outcomes and not the probabilities of each outcome, this is a likely goal for uncertainty situations. It is possible that a conservative manager might know the probability distribution and still have this goal.

(c) Minimize Regret in Each Time Period. Regret is defined as the cost of making a wrong decision. The manager who is concerned about "what could have been" might have this goal. Many farmers make decisions as if they are motivated by the desire to minimize regret. For example, managers who insure property usually know that each insurance premium is more than the value of the property times the probability (even though they don't know the probability) that it will be lost during the time covered by the premium. However, many managers do insure, perhaps reasoning that if they do insure and the property is not lost, their regret will be the value of the insurance premium. If they do not insure and the property is lost, their regret will be the difference between the value of the lost property and the insurance premium, much greater than each individual insurance premium. Thus, insuring suggests a goal of minimum regret. Minimum regret is an appropriate goal in the risk or uncertainty situation because the probability distribution may be known, but it does not have to be.

(4) Empirical results are presented after the analytical technique has been developed in every chapter except the insect control

chapter. These results are obtained by applying the analytical techniques to the available information.

(5) The summary is the last subdivision in each chapter. In this section, a brief summary of the chapter is given.

To review, the procedure used in each chapter will be problem setting, available information, analytical technique, empirical results, and summary.

Format of Remainder of Thesis

The problem attacked and the objectives of this study are stated in the foregoing discussion. The following outline gives the organization of this study and furnishes a preview of the method by which the objectives of this thesis are obtained.

Chapter II--Planting

Problems regarding seeding rate and replanting are examined, using marginal analysis and budgeting.

Chapter III--Fertilizer Rates

Production surfaces for fertilizer rates are estimated, using regression equations. Marginal analysis and budgeting are used to evaluate the economic consequences of alternative fertilizer rates.

Chapter IV--Insect Control

The cotton insect control problem is analyzed as a strategy game against nature. Various alternatives available to farmers and the consequences of each are discussed. Data needed to play the game against nature are specified, and techniques of obtaining data are suggested.

Chapter V--Mechanical Harvesting

The budgeting technique is used to analyze mechanical harvesting data from Agricultural Engineering experiments, and the resulting net returns are discussed. The compatibility between the normal net returns and various farmer's goals are indicated. An analysis is made of possible relationships between alternative harvesting techniques and product prices.

Chapter VI--Summary.

CHAPTER II

COTTON PLANTING PRACTICES

Problem Setting

Two major problems regarding planting practices which Oklahoma cotton producers face are as follows:

(1) What seeding rate should be used?

(2) Should cotton be replanted?

These problems are discussed and analyzed individually in this chapter. Harvesting method, fertilizer, moisture cultural practice (irrigation or dryland), and the type of year occurring may affect the optimum plant population, (i.e., plant population and these practices may interact). In the forthcoming analysis effects of the above practices are considered. Other practices such as cultivating are assumed to have no influence on seeding rates.

Seeding Rate

Emphasis is placed on choice of seeding rate as controllable input affecting plant population per acre and yield. That is, yield = function (seeds, given other production inputs and practices). In analyzing effects of a change in seeding rate, harvesting method, fertilizer, moisture conditions, and type of year are assumed given.

The optimum seeding rate can be determined if the additional revenue, basically, additional cotton times cotton prices net of harvesting cost, and additional cost (e.g. additional seed and planting cost) resulting from increases in seeding rates are known for the given harvesting method. Seed is relatively inexpensive compared to the value of cotton. Therefore, the optimum production strategy and maximum production may not differ greatly.

Replanting

Each year thousands of acres of cotton are replanted. Apparently farm managers think net returns can be increased by replanting, although replanting is an expensive and time consuming operation. Conditions under which net returns may be increased will be analyzed. To estimate effects of replanting on net returns, the revenue and costs which change with replanting must be estimated.

Data Available

Physical Data

The Agricultural Engineering Department, Oklahoma Agricultural Experiment Station, has conducted cotton plant population experiments since 1952 (except 1958). The yield corresponding to the seeding rate and plant population at harvest has been recorded in almost every year (see Tables I, II, and III). Thus, basic data for predicting yields resulting from alternative seeding rates, given other practices, are provided by these experiments. The 1952 through 1957 experiments were conducted under dryland conditions.

> The influence of plant population on plant conformation, cotton harvesting and ginning characteristics was studied at the Chickasha Cotton Research Station from 1952 through 1957. Each of these years, five to 12 different populations were tested. The field design was a randomized block with three or more replications.

TABLE I

SEEDING RATES, HARVEST STANDS, STRIPPED YIELDS, AND TOTAL YIELDS FOR IRRIGATED ACALA 44 COTTON, CHICKASHA, OKLAHOMA, 1959-1961[a]

	1961			1960			1959		
S	Y_s	Y_t	P	Y_s	Y_t	P	Y_s	Y_t	P
30	307	334	3.4	606	631	4.76	718	814	15.06
60	480	539	12.5	702	727	10.72	706	804	27.84
90	543	588	22.8	717	754	18.20	716	801	43.65
120	529	551	16.5	811	851	16.76	665	743	49.20
150	498	518	21.5	780	815	17.20	686	752	69.45
180	515	542	25.1	704	747	20.76	693	761	83.70

[a]The yields obtained in these experiments are given as pounds of clean seed cotton in "Cotton Mechanization in Oklahoma," Oklahoma Agricultural Experiment Station, Agricultural Engineering Annual Reports, 1959-1961. The pounds of lint per acre were computed using the seed-lint ratio given in the Annual Report for each year.

Y_s = Stripped yield (lbs. lint per acre)

Y_t = Total yield (lbs. lint per acre)

P = Harvest stand (1,000 plants per acre)

S = Seeding rate (1,000 seeds per acre).

TABLE II

SEEDING RATES, HARVEST STANDS, AND TOTAL YIELDS FOR DRYLAND PARROTT COTTON, CHICKASHA, OKLAHOMA, 1957-1956[a]

S	1957 Y_t	1957 P	1956 Y_t	1956 P
30	268	15.00	131	10.00
60	267	30.00	157	20.00
90	237	50.00	153	30.00
120	242	75.00	210	50.00
150	251	100.00	188	70.00
180	216	130.00	179	90.00

[a]The yields obtained in these experiments are given as pounds of clean seed cotton in "Cotton Mechanization in Oklahoma," Oklahoma Agricultural Experiment Station, Agricultural Engineering Annual Reports, 1956-1957. The pounds of lint per acre were computed assuming 37.5 percent of clean seed cotton was lint.

Y_t = Total yield (lbs. lint per acre)

P = Harvest stand (1,000 plants per acre)

S = Seeding rate (1,000 seeds per acre)

TABLE III

SEEDING RATES, HARVEST STANDS, AND TOTAL YIELDS FOR DRYLAND LOCKETT NO. 1 COTTON, CHICKASHA, OKLAHOMA, 1952-1955[a]

1955			1954			1953		1952	
S	Y_t	P	S	Y_t	P	Y_t	P	Y_t	P
7	636	3.6	13.1	200	6.2	596	9	272	12
23	711	7.2	25.5	229	13.6	529	14	244	16
44	663	14.8	38.8	218	19.4	555	19	242	20
88	696	25.6	49.9	206	25.6	622	21	210	23
210	627	67.8	59.8	172	33.6	534	25	188	25
			76.1	129	43.4	622	29	221	32
			85.3	131	43.5	488	34	212	37
			100.1	169	56.1	491	40	176	41
			110.7	172	58.4	499	43	191	44
			125.4	114	63.5	476	53	150	58
						452	68		

[a]The seeding rate was not recorded in 1952 or 1953. The yields obtained in these experiments are given as pounds of clean seed cotton in "Cotton Mechanization in Oklahoma," Oklahoma Agricultural Experiment Station, Agricultural Engineering Annual Reports, 1952-1955. The pounds of lint per acre were computed assuming 37.5 percent of clean seed cotton was lint.

Y_t = Total yield (lbs. lint per acre)

P = Harvest stand (1,000 plants per acre)

S = Seeding rate (1,000 seeds per acre).

The variety of cotton planted was Lockett No. 1 in 1952-53-54 and '55 and Parrott in 1956-57. All plots were planted with one planter although some changes in plates were made from year to year. In 1955-56 and '57, cotton was planted in the plateau profile seedbed. Acid delinted seed was used.

Each year the cotton was harvested with a commercial two-row cotton stripper. The stripper had a single steel roll stripping mechanism for each row. In 1955-56 and '57, the field plots were sufficiently large to furnish enough cotton for ginning tests.[1]

In 1959-1961 experiments were performed to study plant population-yield relationships on irrigated cotton. Acid delinted Acala 44 cottonseed was planted at six seeding rates, 30,000, 60,000, 90,000, 120,000, 150,000, and 180,000 seeds per acre. A randomized block field test with six replications was used.

In this study, the seeding rates are converted from 1,000 delinted seeds per acre to pounds delinted seeds per acre. The number of seeds per pound will depend upon the variety because varieties have different sizes of seed. Acala 44 seed is fairly large, while Lockett No. 1 and Parrott seed is small. It is assumed that on the average 4,286 Acala 44 seeds equal one pound and 5,000 Parrott or Lockett No. 1 seeds equal one pound.

Monthly totals of rainfall at the Chickasha Cotton Research Station are listed in the Appendix Table I.

Economic Data

Prices or costs are required for each input and output that changes as seeding rate is varied or replanting vs. not replanting is budgeted.

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[1] Jay G. Porterfield, O. G. Batchelder, and W. E. Taylor, Plant Population for Stripper Harvested Cotton, Oklahoma State University Agricultural Experiment Station Bulletin P-514, September, 1958.

Government support prices for various combinations of grade and staple are usually known at planting time; however, uncontrollable factors such as weather influence grade and staple. Thus, several prices are likely for a given individual's cotton lint. In the absence of better estimates, averages are often satisfactory. A simple average of the individual yearly average prices received by Oklahoma farmers for cotton lint during the five years, 1957 through 1961, was computed to be $.2822 per pound.[2] Twenty-eight cents per pound is used as the price of cotton lint in the planting and fertilizer chapters. Ten cents per pound is deducted for harvesting, hauling, and marketing costs.[3]

Costs of variable factors such as seed are generally known at planting time, but the cost of seed may vary with location, time, or variety. Some farmers buy and plant registered or certified seed every year, but others may "catch" seed at the gin. In an attempt to take into account these practices, two prices ($.18 per pound and $.09 per pound) were used as the prices of cotton seed. Other prices used in this chapter are given and explained as needed.

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[2]The prices for the individual years were obtained from "1959 Supplement to Prices Received by Oklahoma Farmers 1910-1957," Oklahoma State University Agricultural Experiment Station Processed Series P-297, May, 1960, and from "1962 Supplement to Prices Received by Oklahoma Farmers 1910-1957," April, 1962.

[3]Harvesting, hauling, and marketing costs are functions of yield, gin turnout, method of harvesting, scale of operation, and other variables. The budgets in Chapter V (see Tables XXI-XXXII) indicate that harvesting, hauling, and marketing costs were approximately ten cents per pound of lint when custom rates were used.

Analytical Techniques

Thus far, the decision problems related to planting practices have been specified and the available data indicated. This section is devoted to developing analytical techniques which use the available data and indicate a solution to the seeding rate and replanting problems. In this chapter and the fertilizer chapter, perfect knowledge is assumed; therefore, only the goal of maximizing net returns is considered.

Seeding Rate

General analytical techniques are developed in this section for use in the fertilizer chapter as well as in this chapter. The appropriate analytical technique depends on whether the physical data are considered as continuous or discontinuous functions. In the following, a technique is developed for discontinuous relationships and for continuous functions.

Discrete Model

The discrete model is actually a partial budgeting procedure used to determine if increasing a factor of production by discrete amounts increases net returns.

$$\text{Net Returns} = Y \cdot P_y - X \cdot P_x. \qquad (2.1)$$

Net returns will be increased if the addition to total revenue ($Y \cdot P_y$) resulting from adding more of a factor is greater than the addition to variable cost ($X \cdot P_x$). Other costs are constant and can be ignored. The additional revenue from increasing a variable factor is $\Delta Y \cdot P_y$; where, ΔY is read "change in Y," and P_y is the price of cotton per pound after harvesting, hauling, and marketing costs are paid. The additional cost is $\Delta X_1 \cdot P_{x1}$; where, ΔX_1 is read "change in X_1" and P_{x1} is the cost per pound of the factor. Additional amounts of the factor will be added as long as

$$\Delta Y \cdot P_y \geq \Delta X_1 \cdot P_{x1} \qquad (2.2)$$

or

$$\frac{\Delta Y}{\Delta X_1} \geq \frac{P_{x1}}{P_y} \qquad (2.3)$$

Similarly, other factors will be increased as long as

$$\Delta Y \cdot P_y \geq \Delta X_2 \cdot P_{x2} \qquad (2.4)$$

or

$$\frac{\Delta Y}{\Delta X_2} \geq \frac{P_{x2}}{P_y} \qquad (2.5)$$

where, ΔX_2 is read "change in X_2" and P_{x2} is the cost per pound of the second factor. Net returns will be maximized when the equality condition of (2.2) and (2.4) or (2.3) and (2.5) is satisfied as closely as possible.

The discrete model can only be used to compare the discrete levels of factors tested in the experiment. Thus, with the discrete model only the levels of factors actually used in the experiment are considered as possibilities for production strategies.

Continuous Function Method

A continuous function or relationship between factors and products seems reasonable for minutely divisible factors such as seed or fertilizer because practically any amount of the factor can be used in the production process. Ordinarily, experiments are conducted using a few different levels of the factor(s). Then the amounts of product resulting from the discrete levels of factors are considered to be points on a line or function relating factors and products. The functional relationship between factor use and products between observed points is seldom known, but good estimates can be obtained through the use of statistics.

Least squares regression is one of the most common statistical tools used to estimate functional relationships between variables. Least squares regression designates a functional relationship (production function) such that the sum of the squares of the deviations of the observations from the equation will be minimized. That is $\Sigma[\bar{Y} - f(X, X_2, \ldots X_n)]^2$ = SSD = Minimum.

Tests of statistical properties of the estimated relationship can be used to analyze the relationship. Two of these tests are used in this study.

(1) The coefficient of determination (R^2) indicates the percentage of variation of the dependent variable which is explained by the independent variable. The nearer R^2 is to 1.0, the larger percentage of variation which is explained by the estimate. An analysis of regression variance using the "F" test is available for estimating significance of variance explained by regression.[4] It should be remembered that R^2 is simply a selected statistical measure; therefore, logical reason(s) for linking the independent and dependent variables must exist before much confidence should be placed in cause and effect implications, (e.g., spurious correlation may be present).

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[4]See Robert G. D. Steel and James H. Torrie, Principles and Procedures of Statistics, New York, 1960, pp. 287-299, for a discussion of the "t" and "F" tests as related to regression.

(2) The "t" test indicates the significance of each parameter of the production equation and allows decision at a certain confidence level, whether the parameter is vital to the explanation of variation given by the fitted equation.

Since the production function is considered to be continuous, [i.e., $\hat{Y} = f(X_1, X_2)$],

$$\pi = \hat{Y} P_y - \sum_{i=1}^{n} P_{xi} X_i \qquad (2.6)$$

Profit is maximum when $\frac{\partial \pi}{\partial X_i} = 0 = \frac{\partial \hat{Y}}{\partial X_i} P_y - P_{xi}$. From this relationship equations similar to (2.3) and (2.5) are obtained (ΔX_i is infinitesimal).

$$\frac{\partial Y}{\partial X_1} = \frac{P_{x1}}{P_y} \quad \text{or} \quad \frac{\partial f(X_1, X_2)}{\partial X_1} = \frac{P_{x1}}{P_y} \qquad (2.7)$$

$$\frac{\partial Y}{\partial X_2} = \frac{P_{x2}}{P_y} \quad \text{or} \quad \frac{\partial f(X_1, X_2)}{\partial X_2} = \frac{P_{x2}}{P_y} \qquad (2.8)$$

Equations (2.7) and (2.8) are necessary conditions for net returns to be a maximum.[5]

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[5]Sufficient conditions are that equations (2.7) and (2.8) hold and

$$\frac{\partial^2 Y}{\partial X_1^2} < 0, \ \frac{\partial^2 Y}{\partial X_2^2} < 0$$

$$\left[\frac{\partial^2 Y}{\partial X_1 X_2}\right]^2 < \frac{\partial^2 Y}{\partial X_1^2} \cdot \frac{\partial^2 Y}{\partial X_2^2}$$

These are the second order conditions which assure that the production function is concave. Any elementary calculus text indicates the procedure for maximizing continuous functions.

Empirical Results

Seeding Rate

Discrete Model

The discrete model was used to determine returns above seed cost for the stripped yields and total yields obtained from various seeding rates in 1959-1961 irrigated experiments. Results of these computations are given in Table IV. Increasing the price of seed from $.09 per pound to $.18 per pound did not change the optimal production strategy. Returns above seed cost were the highest for seeding rates of 21 pounds per acre, 28 pounds per acre, and seven pounds per acre in 1961, 1960, and 1959, respectively. Farmers ordinarily plant from 15 to 30 pounds of delinted seed per acre on irrigated land. However, rates of 21-28 pounds per acre appear to be a superior strategy. The decrease in yield as the seeding rate increased in 1959 might be a result of the low rainfall during the month of August (see Appendix Table I) and inability to meet water needs at critical times with irrigation.

It should be noted that in each of the three years, the highest returns above seed costs for stripped yield and for total yield resulted from the same seeding rate. Thus, the same rate would be used for cotton to be stripped as well as that to be harvested another way.

Returns above seed costs were computed via the discrete model for dryland conditions in the years 1954-1957 and are given in Table V. In 1954, 1955, and 1957, a seeding rate of between four pounds per acre and six pounds per acre produced the largest returns above seed costs. However, in 1956, 24 pounds per acre was the optimum seeding rate. The

TABLE IV

RETURNS ABOVE SEED COSTS AND YIELDS FOR VARIOUS SEEDING RATES ON IRRIGATED COTTON

Year	Seeding Rate		Stripper Harvest			Total Harvest		
			Returns above seed costs		Stripped Yield	Returns above seed costs		Total Yield
	lbs./ acre	1000 seeds / acre	\$/ acre[a]	\$/ acre[b]	lbs. lint/ acre	\$/ acre[a]	\$/ acre[b]	lbs. lint/ acre
1961	7	30	54.63	54.00	307	59.49	58.86	334
	14	60	85.14	83.88	480	95.76	94.50	539
	21	90	95.85*	93.96*	543	103.95*	102.06*	588
	28	120	92.70	90.18	529	96.66	94.14	551
	35	150	86.49	83.34	498	90.09	86.94	518
	42	180	88.92	85.14	515	93.78	90.00	542
1960	7	30	108.45	107.82	606	112.95	112.32	631
	14	60	125.10	123.84	702	129.60	128.34	727
	21	90	127.17	125.28	717	133.83	131.94	754
	28	120	143.46*	140.94*	811	150.66*	148.14*	851
	35	150	137.25	134.10	780	143.55	140.40	815
	42	180	122.94	119.16	704	130.68	126.90	747
1959	7	30	128.61*	127.98*	718	145.89*	145.26*	814
	14	60	125.82	124.56	706	143.46	142.20	804
	21	90	126.99	125.10	716	142.29	140.40	801
	28	120	117.18	114.66	665	131.22	128.70	743
	35	150	120.33	117.18	686	132.21	129.06	752
	42	180	120.96	117.18	693	133.20	129.42	761

*Highest returns above seed costs in an individual year.

[a]Price of cotton seed = \$.09 per lb. and price of cotton lint after harvesting, hauling, and marketing costs = \$.18 per lb.

[b]Price of cotton seed = \$.18 per lb. and price of cotton lint after harvesting, hauling, and marketing costs = \$.18 per lb.

TABLE V

RETURNS ABOVE SEED COSTS AND TOTAL YIELD FOR VARIOUS SEEDING RATES ON DRYLAND COTTON

Year	Seeding Rate		Returns Above Seed Costs		Total Yield
	lbs./acre	1000 seeds/acre	acre[a]	acre[b]	lbs. lint/acre
1957	6	30	47.70*	47.16*	268
	12	60	46.98	45.90	267
	18	90	41.04	39.42	237
	24	120	41.40	39.24	242
	30	150	42.48	39.78	251
	36	180	35.64	32.40	216
1956	6	30	23.04	22.50	131
	12	60	27.18	26.10	157
	18	90	25.92	24.30	153
	24	120	35.64*	33.48*	210
	30	150	31.14	28.44	188
	36	180	28.98	25.74	179
1955	1.4	7	114.35	114.23	636
	4.6	23	127.57*	127.15*	711
	8.8	44	118.55	117.76	663
	17.6	88	123.70	122.11	696
	42.0	210	109.08	105.30	627
1954	2.6	13.1	35.77	35.53	200
	5.1	25.5	40.76*	40.30*	229
	7.8	38.8	38.54	37.84	218
	10.0	49.9	36.18	35.28	206
	12.0	59.8	29.88	28.80	172
	15.2	76.1	21.87	20.48	129
	17.1	85.3	22.04	20.50	131
	20.0	100.1	28.62	26.82	169
	22.1	110.7	28.97	26.98	172
	25.1	125.4	18.26	16.00	114

*Highest returns above seed costs in an individual year.

[a]Price of cotton seed = $.09 per lb. and price of cotton lint after harvesting, hauling, and marketing costs = $.18 per lb.

[b]Price of cotton seed = $.18 per lb. and price of cotton lint after harvesting, hauling, and marketing costs = $.18 per lb.

yields for all seeding rates were low in 1956. This phenomenon might be accounted for by the low rainfall during most of 1956, but fairly high rainfall during July, 1956. During low rainfall periods, dryland cotton commonly sheds some of its fruit. The low yield may be the result of low rainfall throughout the growing season. The fairly high rainfall during the month of July may have allowed each plant (up to 50,000 plants per acre) to mature a few bolls which would account for the high seeding rate being the optimum production strategy.

Farmers commonly plant from 12 to 18 pounds of delinted cottonseed per acre for dryland conditions. However, on the basis of four years of results, ten pounds or less appears to be a more profitable choice.

Continuous Function Method

Least squares regression was used to derive empirical production functions with the seeding rate as the independent variable. These production equations are given in Tables VI and VII. The numbers above the regression coefficients indicate the probability of the given coefficient being zero.

It may be noted from Table VI that the most profitable seeding rate for 1961, found by using the discrete model, differs a great deal from the most profitable seeding rate found by using the production function method. This discrepancy occurs because a large part of the deviation between the production function and the raw data occurs near the seeding rate of 120,000 seeds per acre. This discrepancy is really not alarming if the returns above seed costs for the two methods are computed, because they only differ by about eight dollars at the most profitable seeding rates. That is, the production function is fairly flat between 90 and

TABLE VI

SEEDING RATE FOR IRRIGATED COTTON[a]

Year	Most Profitable Seeding Rate: Discrete Model				Most Profitable Seeding Rate: Production Function Method				d.f.	R^2	The Regression Equation[c]
	lbs. seed /acre (B)	1000 seeds /acre (B)	lbs. seed /acre (C)	1000 seeds /acre (C)	lbs. seed /acre (B)	1000 seeds /acre (B)	lbs. seed /acre (C)	1000 seeds /acre (C)			
1961	21	90	21	90	28.2	121	27.5	118	3	.76	$Y_t = 212.500 + \overset{.08^b}{6.033}S - \overset{.11}{.0245}S^2$
1961	21	90	21	90	29.2	125	28.5	122	3	.86	$Y_s = 178.00 + \overset{.04}{5.845}S - \overset{.06}{.0229}S^2$
1960	28	120	28	120	28.2	121	27.5	118	3	.88	$Y_s = 464.200 + \overset{.03}{5.129}S - \overset{.04}{.0207}S^2$
1960	28	120	28	120	28.7	123	28.0	120	3	.91	$Y_t = 481.399 + \overset{.02}{5.363}S - \overset{.03}{.0213}S^2$
1959	7	30	7	30	--	--	--	--	4	.70	$Y_t = 827.067 - \overset{.04}{.456}S$
1959	7	30	7	30	--	--	--	--	4	.39	$Y_s = 720.933 - \overset{.19}{.225}S$

[a]These experiments were performed on McLain silt loam soil on the Cotton Research Station near Chickasha, Oklahoma.

Columns (B) were computed assuming 4286 seed/lb. at $.09/lb. = $.021/1000 seeds.

Columns (C) were computed assuming 4286 seed/lb. at $.18/lb. = $.042/1000 seeds.

For Columns (B) and (C) the price of cotton lint was considered to be $.18/lb. after harvesting, hauling, and marketing costs have been paid.

[b]For this and succeeding equations, numbers appearing above regression coefficients are probability levels obtained from the student "t" test.

[c]S = seeding rate (1000 seeds per acre).

TABLE VII

SEEDING RATE FOR DRYLAND COTTON[a]

Year	Most Profitable Seeding Rate								d.f	R^2	The Regression Equation[b]
	Discrete Model				Production Function Method						
	lbs. seed /acre (B)	1000 seeds /acre (B)	lbs. seed /acre (C)	1000 seeds /acre (C)	lbs. seed /acre (B)	1000 seeds /acre (B)	lbs. seed /acre (C)	1000 seeds /acre (C)			
1957	6	30	6	30	--	--	--	--	4	.68	$Y_t = 277.133 - \overset{.05}{0.289}S$
1956	24	120	24	120	26	130	24	120	3	.73	$Y_t = 89.500 + \overset{.17}{1.401}S - \overset{.27}{.005}S^2$
1955	4.6	23	4.6	23	17.2	86	15.2	76	2	.53	$Y_t = 650.734 + \overset{.09}{.964}S - \overset{.34}{.005}S^2$
1954	5.1	25.5	5.1	25.5	--	--	--	--	8	.61	$Y_t = 230.669 - \overset{.008}{0.828}S$

[a]The pounds of lint were computed by assuming that 37.5 percent of clean seed cotton was lint. Lockett No. 1 was the variety used in 1952-1955, but the variety was Parrott in 1956 and 1957. These experiments were performed on Reinach silt loam soil on the Cotton Research Station near Chickasha, Oklahoma.

Columns (B) were computed assuming 5000 seeds/lb. at \$.09/lb. = \$.018/1000 seeds.

Columns (C) were computed assuming 5000 seeds/lb. at \$.18/lb. = \$.036/1000 seeds.

For Columns (B) and (C) the price of cotton lint was considered to be \$.18/lb. after harvesting, hauling, and marketing costs have been paid.

[b]S = seeding rate (1000 seeds per acre).

120 thousand seeds per acre in 1961. In 1960, the two methods give results which nearly coincide. It is noted that the price of seed influenced the optimum seeding rate very little.

All of the equations of total yield of irrigated cotton score well on the statistical tests. The 1961 and 1960 quadratic equations of stripped yield score well on the statistical tests, but the 1959 equation is linear and only explains 39 percent of the variation.

The equations for dryland cotton are given in Table VII. The equations for 1954 and 1957 are linear with negative slopes. The equation for 1956 explains seventy-three percent of the variation. The coefficients of P and P^2 are significant at the seventeen and twenty-seven percent levels, respectively.

Fifty-three percent of the variation in yield in 1955 is explained by the variation in the seeding rate. The coefficients of P and P^2 could occur by chance alone nine and thirty-four percent of the time, respectively. The most profitable seeding rate for 1955 found by using the discrete model differs a great deal from the most profitable seeding rate found by using the continuous function method. This discrepancy occurs because a large part of the deviation between the production function and the raw data occurs near the seeding rate of 80,000 seeds per acre. This discrepancy causes returns above seed costs computed by the two methods to differ by only about five dollars per acre.

Replanting

The yield of lint resulting from a given plant population is one of the most important estimates which a farm manager must make when considering replanting.

Least squares regression has been used to derive empirical production functions with plant population as the independent variable. Table VIII gives a summary of the production equations for irrigated cotton. Each of these equations will be discussed briefly.

Equation 1: $Y_s = 210.489 + \overset{.01}{31.212}P - \overset{.03}{.764}P^2$ $\qquad R^2 = .96$

Equation 1 scores well on the tests of statistical significance. Ninety-six percent of the variation is explained by the equation. The coefficients of P and P^2 are significant at the one and three percent levels.

Equation 2: $Y_t = 233.113 + \overset{.03}{33.862}P - \overset{.06}{.864}P^2$ $\qquad R^2 = .92$

The t-test of the parameters and the R^2 for this equation are significant. It might be noted from Table VIII that the stripped yield and total yield are a maximum at approximately the same population.

Equation 3: $Y_s = 392.359 + \overset{.08}{48.579}P - \overset{.12}{1.612}P^2$ $\qquad R^2 = .79$

Seventy-nine percent of the variation in the stripped yield is explained by the variation in plant population. Eight and twelve percent of the time the coefficient of P and P^2, respectively, might be expected to be caused by chance alone.

Equation 4: $Y_t = 426.737 + \overset{.10}{47.913}P - \overset{.16}{1.538}P^2$ $\qquad R^2 = .79$

Equation 4 scores fairly well on the statistical tests; however, not as well as the three previously mentioned equations did. The stripped yield reaches maximum at a slightly lower plant population than the total yield.

Equation 5: $Y_s = 717.702 - \overset{.26}{.423}P$ $\qquad R^2 = .28$

The raw data for equations 5 and 6 indicated that linear equations would fit better than quadratic equations. Equation 5 does not score

TABLE VIII

PLANT POPULATION FOR IRRIGATED COTTON[a]

Year	Equation Number	d.f.	R^2	Population at Which Yield is a Maximum[b] 1,000 plants/acre	The Regression Equation[b]
1961	1	3	.96	20.4	$Y_s = 210.489 + \overset{.01}{31.212}P - \overset{.03}{.764}P^2$
1961	2	3	.92	19.6	$Y_t = 233.113 + \overset{.03}{33.862}P - \overset{.06}{.864}P^2$
1960	3	3	.79	15.1	$Y_s = 392.359 + \overset{.08}{48.579}P - \overset{.12}{1.612}P^2$
1960	4	3	.79	15.6	$Y_t = 426.737 + \overset{.10}{47.913}P - \overset{.16}{1.538}P^2$
1959	5	4	.28	--	$Y_s = 717.702 - \overset{.26}{.423}P$
1959	6	4	.60	--	$Y_t = 823.926 - \overset{.08}{.930}P$

[a]These experiments were performed with Acala 44 cotton on McLain silt loam soil on the Cotton Research Station near Chickasha, Oklahoma.

[b]P = plant population at harvest (1,000 plants/acre).

well on the tests of significance. The equation only explains about twenty-eight percent of the variation. The coefficient of P is not significant at the twenty-five percent level. The minus sign (-) on the coefficient of P indicates that the yield decreased as the population increased. Therefore, within the range of the experiment, the lowest population had approximately the highest yield. Equation 5 seems to indicate that plant population had little effect on stripped yield in 1959.

Equation 6: $Y_t = 823.926 - \overset{.08}{.930}P$ $\qquad R^2 = .60$

Equation 6 scores fairly well on the tests of significance. The coefficient of P is negative; thus, the minimum population had approximately the highest yield. Sixty percent of the variation in yield is explained by variation in the population.

Table IX gives a summary of the production equations for dryland conditions. The production equations for the years 1952, 1953, 1954, 1957 are linear and have a negative P coefficient which indicates that the total yield tends to decrease as the population increases. Thus, if a manager anticipates a year similar to these years, he would not strive to obtain a population above the minimum used in the experiments.

All of the production equations except 1955 score fairly well on the statistical tests. The coefficient of P for 1952, 1953, and 1954 are all significantly different from zero at the one percent probability level.

The population and seeding rate equations derived thus far can be utilized in estimating expected yields from present stands and expected stands for use in partial budgeting the replanting alternatives.

TABLE IX

PLANT POPULATION FOR DRYLAND COTTON[3]

Year	d.f.	R^2	Population at Which Yield is a Maximum 1,000 Plants /acre	The Regression Equation
1957	4	.67	--	$Y_t = 271.602 - \overset{.04}{.372}P$
1956	3	.83	62.3	$Y_t = 99.819 + \overset{.06}{3.115}P - \overset{.09}{.025}P^2$
1955	2	.48	30.2	$Y_t = 651.247 + \overset{.50}{2.841}P - \overset{.41}{.047}P^2$
1954	8	.60	--	$Y_t = 230.430 - \overset{.008}{1.553}P$
1953	9	.56	--	$Y_t = 613.915 - \overset{.008}{2.504}P$
1952	8	.77	--	$Y_t = 279.017 - \overset{.001}{2.221}P$

[a]The pounds of lint were computed by assuming that 37.5 percent of clean seed cotton was lint. Lockett No. 1 was the variety used in 1952-1955, but the variety was Parrott in 1956 and 1957. These experiments were performed on Reinach silt loam soil on the cotton Research Station near Chickasha, Oklahoma.

The 1961 equations will now be used in an example to illustrate the procedure.

Suppose that on May 25, 1961, a hard rain thinned a farmer's irrigated cotton to approximately 16,000 plants per acre. This farmer knows that there is no way of being absolutely sure whether he should replant or leave his cotton. However, he has carefully studied the situation and has made the following estimates of cost and return items.

Items which change	Abbreviation	Units	Alternatives: Not Replanting	Alternatives: Replanting
Price of lint[a]	P_y	\$/lb.	.18	.17
Price of seed	P_x	\$/lb.	--	.09
Planting costs	$P_{x2}X_2$	\$/acre	--	1.70
Weed control costs[b]	$P_{x3}X_3$	\$/acre	14.00	11.00

[a]Price of lint will likely be lower for the replanted cotton because a larger percentage of it will be harvested late in the season. See Chapter V, p. 106.

[b]Replanting kills some weeds; therefore, less hand hoeing is required.

The first step in determining the effect replanting will have on net returns is to determine net returns resulting from replanting. For a given year this can be done by combining prices with the equations in Tables VI and VII. For 1961 the total yield equation is

$$Y_t = 212.500 + 6.033S - .0245S^2$$

If the farmer replants, he will certainly attempt to maximize net returns, i.e., use the seeding rate which maximizes net returns. For this example, the net returns equation for replanting is

$$NR_r = .17 \left[212.500 + 6.033\,(121) - .0245\,(121)^2\right] - .09(28) - 1.70 - 11.00$$

$$NR_r = \$84.06$$

The second step is to determine net returns if the cotton is not replanted. For this example $NR_{nr} = .18Y - 14.00$, and Y is a function of population. Thus, for a given population, expected NR_{nr} can be computed and compared with NR_r to determine which alternative results in the highest net returns.

Another approach to the replanting problem might be to use the information in the first two steps and determine what yield is necessary for the not replanting alternative to result in exactly the net returns obtained from replanting.

$NR_r = NR_{nr}$. Therefore, $.18Y - 14.00 = \$84.06$.

Solving for Y:

$$Y = 545 \text{ lbs. of lint/acre}$$

The above 545 lbs. is the break-even yield, i.e., the yield which the farmer must obtain from his first planting to be exactly indifferent about replanting.

The break-even population can be determined by using the above yield and equations in Tables VIII and IX. For 1961

$$Y_t = 233.133 + 33.862P - .864P^2$$

$$545 = 233.133 + 33.862P - .864P^2$$

Solving for P:

$$P = 14.6$$

Since the farmer has more than the break-even population, he probably will not replant. The break-even yields and populations for all of the years were computed by the above procedure and are given in Table X.

The equations in 1952, 1953, 1954, 1957, and 1959 are linear and have a negative slope; therefore, farmers would not replant if costs are as assumed in the example and, if the population is as high as the lowest population tested in the respective years.

In 1956, no population tested resulted in a yield as high as the break-even yield (253 lbs.); therefore, replanting would not be practiced if the population is 10,000 plants or greater (lowest population tested).

The break-even yields and populations in Table X were computed assuming specified prices and perfect knowledge. These break-even points might be adjusted for lack of confidence in obtaining the maximum yield after replanting or for changes in prices.

Summary

Total yield and stripped yield were a maximum at the same seeding rate in each of three years. This seems to indicate that the seeding rate does not need to be increased because of plans to use stripper harvesting.

Seed is cheap, relative to cotton; therefore, farmers can probably use a seeding rate giving maximum yield for a wide range of cotton and cottonseed prices.

Production equations of the yields resulting from various plant populations were derived. In 1961, the yield for irrigated cotton was a maximum when the plant population was approximately 20,000 plants per

TABLE X

BREAK-EVEN YIELDS AND POPULATIONS FOR REPLANTING, CHICKASHA, OKLAHOMA, 1952-1961[a]

Item	Total Yield Lint lbs./acre	Total Yield Population 1000 Plants /acre	Stripped Yield Lint lbs./acre	Stripped Yield Population 1000 Plants /acre	Lowest Population Tested 1000 Plants /acre
1961 Irrigated Acala 44	545	14.6	513	15.8	3.4
1960 Irrigated Acala 44	766	10.9	731	11.0	4.76
1959 Irrigated Acala 44	--	b	--	b	15.0
1957 Dryland Parrott	--	b	--	--	15.0
1956 Dryland Parrott	253	c	--	--	10.0
1955 Dryland Lockett No. 1	657	2.1[d]	--	--	3.6
1954 Dryland Lockett No. 1	--	b	--	--	6.2
1953 Dryland Lockett No. 1	--	b	--	--	9.0
1952 Dryland Lockett No. 1	--	b	--	--	12.0

[a]Assuming cotton lint price and cotton seed price are \$.18 and \$.09 per lb., respectively. Experiments were not performed in 1958.

[b]The regression equations have a negative slope; therefore, replanting would not be done if the population is as great or greater than the lowest population tested.

[c]No population tested resulted in a yield as high as 253 lbs. per acre.

[d]The break-even population in 1955 (2.1 according to the regression equations) is lower than the lowest population tested.

acre and the seeding rate was 21 pounds per acre. In 1960, the maximum yield was forthcoming from about 15,000 plants per acre and a seeding rate of about 28 pounds per acre. In 1959, the yield tended to decrease as the population increased. The lowest population (15,060) and the lowest seeding rate (7 pounds per acre) produced the highest yield. Based on three years of data, planting 21-28 pounds per acre appears to be a superior strategy for irrigated land.

In four out of six years, the yield of dryland cotton tended to decrease as the population increased. In three years out of four, the optimum seeding rate for dryland cotton was from four to six pounds per acre. However, in 1956, the optimum seeding rate was approximately 24 pounds per acre. Based on the data at hand, a long term recommendation of 10 pounds per acre or less seems reasonable.

Assuming a net price of $.18 per pound for cotton lint and $.09 per pound for cotton seed, a farmer who is irrigating could increase his net returns by replanting in years such as 1961 only if his population is below approximately 15,000 plants per acre. In years such as 1960, it is profitable to replant only if the plant population is below approximately 11,000 plants per acre.

Additional research is needed at low seeding rates and plant populations before break-even populations can be determined for dryland conditions.

CHAPTER III

FERTILIZER RATES

Problem Setting

Many inputs such as land, labor, seed, fertilizer, insecticides, and machinery are required to produce cotton. In this chapter economics of fertilizing cotton will be analyzed with other inputs fixed. As indicated in Chapter II, the most profitable input rate is found by determining whether the additional revenue obtained is greater than the cost of the additional quantity applied. Most profitable rates of nitrogen and phosphorus for cotton production are derived from fertilizer data obtained from experiments in three state areas.

Data[1]

Physical Data

Data for this analysis were obtained from four fertility experiments located in southwestern Oklahoma. Fertility experiments were conducted at the Irrigation Research Station at Altus, Cotton Research Station at Chickasha, and the Sandy Land Research Station at Mangum. The soil

[1]See R. M. Reed, J. R. Gingrich, and B. B. Tucker, "Cotton Management and Fertility Research Progress Report, 1961," Oklahoma State University Agricultural Experiment Station Processed Series P-420, June, 1962, and R. M. Reed, J. R. Gingrich, and B. B. Tucker, "Cotton Fertilization Research Progress Report, 1960," Oklahoma State University Agricultural Experiment Station Processed Series P-387, June, 1961, for full discussion of experimental procedure.

characteristics at these stations are given below.

Location	Soil Type	pH	Percent O.M.	Available P	Available K
Altus	Hollister silty clay loam	6.5	3.5	very high	very high
Chickasha (dryland)	Reinach silt loam	6.3	1.5	very high	high
Chickasha (irrigated)	McLain silty clay loam	6.2	2.3	very high	very high
Mangum	Brownfield loamy sand	6.6	0.4	medium	medium

The experimental design was randomized block normally replicated four times. Fertilizer was applied at planting time approximately two inches to the side and four inches below the seed. All treatments are expressed in pounds of N, P_2O_5, and K_2O per acre.

Experiments are analyzed in two categories, dryland fertility at Mangum and Chickasha, and irrigated fertility at Altus and Chickasha. The experiments for the individual locations will be discussed in the forthcoming paragraphs. Yield data for the experiments are contained in Appendix Tables II, III, IV, and V.

Dryland Fertility Experiments

Mangum:

> This experiment was initiated in 1958 on an area of the Station which had not been deep-plowed. However, the 1958 crop was a failure because of sandstorm damage in late June. Rainfall was 5 1/2 inches above normal for the 1959 growing season with only August below normal. The average yields in 1959 were similar to those obtained at Chickasha. The 1960 season was extremely favorable. The rainfall during the growing season was eight inches above normal. Only May and September had below normal amounts.[2]

[2]Reed, et al., "Cotton Fertilization Research Progress Report, 1960," p. 4.

The 1961 season was very favorable, but not as good as 1960. There was a greater moisture deficit in May of 1961 than in May, 1960. The August rainfall for 1961 was normal, while in 1960, the August rains were one inch above normal.[3]

Parrott was the variety used for this test in 1958, 1959, and 1960. In 1961, Lankart 57 was used for this experiment.

An analysis of variance for 1961 indicated that the treatments were significantly different at the one percent probability level.

Chickasha:

The average yield for 1961 was similar to those obtained in 1958 and 1960. Rainfall during the 1961 growing season (May through August) was almost two inches above normal. Moisture deficiencies in May and June were offset by July rains which were over five inches above normal. Individual fertilizer treatment responses have been somewhat erratic.[4]

In 1959, the average yields were lower [than 1958, 1960, or 1961] although the rainfall during the growing season was five inches above normal. These lower yields may be partially attributed to the distribution of the rainfall, which was considerably above normal in July, but below normal in June and August. Individual fertilizer treatments have been erratic during the past three years. This may be caused by moving the experiment [in 1959 and 1960] in an attempt to obtain a more uniform soils.[5]

Parrott was the variety used for this test in 1958, 1959, and 1960. In 1961, the variety was changed to Lankart 57.

An analysis of variance for 1961 indicated that the treatments were not significant at the five percent level. Regression analysis for other years indicated little treatment effect and erratic patterns. Thus, additional experimentation is needed to provide a basis for fertilizer recommendations.

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[3] Reed, et al., "Cotton Management and Fertility Research Progress Report, 1961," p. 5.

[4] Ibid.

[5] Reed, et al., "Cotton Fertilization Research Progress Report, 1960," pp. 2 and 4.

Irrigated Fertility Experiments

Altus:

The average yield differences between years may be attributed to varietal responses and climatic conditions. Parrott was planted in 1958 and the yields were low. In 1959, Acala 44 was planted originally and it was necessary to replant with Stoneville 62 because it was too late in the season for Acala, which is slow maturing. Austin was the test variety used in 1960. This variety is adapted to irrigated conditions and is blight resistant. The yields were improved greatly in 1960 and would have been somewhat higher if the crop had not received hail damage at harvest time. The check plots have outyielded the fertilizer treatments over the three-year span. This may be attributed to a very fertile area and a residual effect of previous fertilizer applications.[6] The site of the fertility test was changed in 1961.[7]

Only 1961 data were analyzed because fertilizer will certainly not pay when the check plot yields more than the fertilized plots. It was assumed that optimum moisture conditions were maintained by irrigation. Austin variety was used for this test in 1961.

An analysis of variance for 1961 indicated that the treatments were significantly different at the one percent probability level.

Chickasha:

This experiment was begun on a newly leveled area in 1958. It was then moved to its present location in 1959. The average yields in 1958 are lower because the leveled land had not settled and there were also a few low areas in the field. It was necessary to make a yield adjustment in 1960 because of a skippy stand of Stoneville 62.[8]

Austin was the variety used for this experiment in 1961. It is assumed that optimum moisture conditions were maintained by irrigation.

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[6] Ibid., pp. 4 and 6.

[7] Reed, et al., "Cotton Management and Fertility Research Progress Report, 1961," p. 9.

[8] Reed, et al., "Cotton Fertilization Research Progress Report, 1960," p. 6.

An analysis of variance for 1961 indicated that the treatments were not significant at the five percent level.

Economic Data

The following prices are assumed:

Nitrogen	$ .13 per lb.
Phosphorus	$ .10 per lb.
Cotton lint	$ .28 per lb.[9]
Harvesting, hauling, and marketing cost on additional yield	$ .10 per lb.

The cost for nitrogen and phosphorus includes the cost of application. It is recalled from Chapter I that the costs used in this thesis include either an interest cost or opportunity cost.

Empirical Results

The data from the four experiments were analyzed by the discrete model (developed in Chapter II), i.e., treatments were considered as the only possible levels and combinations of inputs, and by the continuous function model. Results of each model are discussed individually then the results are compared.

Discrete Model

Dryland Fertility Experiments

Mangum:

The yields and returns above fertilizer costs for the Mangum dryland fertility experiments are given in Table XI. In 1959, 60 pounds of

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[9]See Chapter II, p. 19, for a brief discussion of cotton lint price.

TABLE XI

COTTON FERTILITY TEST ON DRYLAND BROWNFIELD LOAMY SAND AT MANGUM, OKLAHOMA, 1959-1961

		- Nitrogen -													
		0		20		40		60		80		100	
Year	Phosphorus	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]
	Pounds	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
1959	0	319	0.00	399	11.80	489	25.40*	471	19.56				
	20	430	17.98	446	18.26	430	12.78	480	19.18				
	40	327	-2.56	425	12.48	423	9.52	511	22.76				
1960	0	486	0.00	691	34.30	761	44.30	892	65.28				
	20	604	19.24	698	33.56	818	52.56	955	74.62				
	40	482	-4.72	674	27.24	873	60.46	1019	84.14*				
1961	0	383	0.00	--	--	595	32.96	818	70.50				
	20			614	36.98	729	55.08	891	81.64*	757	54.92		
	40			706	51.54	735	54.16	778	59.30	879	74.88	772	53.02
	60							773	56.40				
Average	0	396	0.00	545[b]	24.22	615	34.22	727	51.78				
	20	517[b]	19.78	586	29.60	659	40.14	775.3	58.47*	757[c]	52.58		
	40	404.5[b]	-2.47	601.7	30.43	677	41.38	769.3	55.39	879[c]	72.54	772[c]	50.68
	60							773[c]	54.06				

*Highest net returns for individual year or four-year average.

[a]Returns above fertilizer costs were computed in each year by subtracting the returns for the check plot from the returns (after fertilizer costs were paid) for each of the other treatments. The following prices were assumed:

(1) Nitrogen - $.13 per lb.
(2) Phosphorus - $.10 per lb.
(3) Harvesting and marketing costs on additional yield - $.10 per lb.
(4) Cotton lint - $.28 per lb.

[b]Average of only two years.

[c]Only one year of data available.

nitrogen and 40 pounds of phosphorus produced the highest yield, but the 40 pounds of nitrogen and no phosphorus treatment had the highest returns above fertilizer cost. The cost of the 20 pounds additional nitrogen and 40 pounds additional phosphorus are greater than the returns from the additional yield. The lack of rainfall in August might account for the low returns resulting from larger application of fertilizer, particularly phosphorus. The data in 1959 closely follows the expected model. That is, the data seems to be compatible with the law of diminishing returns.

In 1960, the season was very favorable and August rainfall was one inch above normal. This favorable season could be responsible for the 60 pounds of nitrogen and 60 pounds of phosphorus treatment having the highest net returns. The data for 1960 were consistent with the principle of diminishing returns.

In 1961, 60 pounds of nitrogen and 20 pounds of phosphorus resulted in the highest net returns. Low rainfall in May and normal rainfall in August may have given an advantage to the moderate fertilizer rate. The 1961 data were consistent with the expected model.

The moderate fertilizer rate, 60 pounds of nitrogen and 20 pounds of phosphorus resulted in the highest three-year average net returns. However, to have followed this strategy in each year would have resulted in yearly losses of $6.22 and $9.52 in 1959 and 1960, respectively, per acre.

Chickasha:

The yields and returns above fertilizer costs for the dryland fertility experiments at Chickasha are given in Table XII. The results

TABLE XII

COTTON FERTILITY TEST ON DRYLAND REINACH SILT LOAM SOIL AT CHICKASHA, OKLAHOMA, 1958-1961

		- Nitrogen -									
		0		20		40		60		80	
Year	Phosphorus	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]
						- Per Acre -					
	Pounds	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
1958	0	521	0.00	640	18.82	561	2.00	559	-0.96		
	20	543	1.96	675	23.12*	580	3.42	637	11.08		
	40	595	9.32	580	4.02	565	-1.28	509	-13.96		
1959	0	465	0.00*	413	-11.96	458	-6.46	463	-8.16		
	20	410	-11.90	471	-3.52	378	-22.86	402	-21.14		
	40	456	-5.62	450	-9.30	479	-6.68	425	-19.00		
1960	0	555	0.00	543	-4.76	622	6.86	575	-4.20		
	20	567	.16	553	-4.96	568	-4.86	564	-8.18		
	40	621	7.88*	579	-2.28	551	-9.92	574	-8.38		
1961	0	528	0.00	596	9.64*	561	.74	698	4.80		
	20	541	.34	560	1.16	543	-4.50	579	-0.62		
	40	564	2.48	572	1.32	558	-3.80	556	-6.76	564	-7.92
Average	0	517.2	0.00	548.0	2.94	550.5	.79	548.8	-2.11		
	20	515.2	-2.36	564.8	3.97*	517.2	-7.20	545.5	-4.71		
	40	559.0	3.52	545.2	-1.56	538.2	-5.42	516.0	-12.02	564[b]	-5.98

*Highest net returns for individual year or four-year average.

[a]Returns above fertilizer costs were computed in each year by subtracting the returns for the check plot from the returns (after fertilizer costs were paid) for each of the other treatments. The following prices were assumed:

(1) Nitrogen - $.13 per lb.
(2) Phosphorus - $.10 per lb.
(3) Harvesting and marketing costs on additional yield - $.10 per lb.
(4) Cotton lint - $.28 per lb.

[b]Only one year of data available.

from the fertilizer treatments in this experiment have been very erratic and inconclusive. Additional long-run experimentation is needed to determine the profitability of fertilizing cotton on this soil. The data in Table XII do not conform to the expected model.

Irrigated Fertility Experiments

Altus:

Only the 1961 data were analyzed. The site of the fertility test was changed in 1961 to plots allowing more sensitive tests of response.

The 1961 yields and returns above fertilizer costs for the irrigated fertility experiment at Altus are given in Table XIII. The 160 pounds of N and 40 pounds of P treatment resulted in the highest net returns in 1961. However, the net returns for 80 pounds of nitrogen and 40 pounds of phosphorus are only $3.46 lower than the 160 pounds of nitrogen and 40 pounds of phosphorus treatment. The 1961 80 pounds of nitrogen and 80 pounds of phosphorus yield is lower than expected, but the data approximated the expected model.

Chickasha:

The yields and returns above fertilizer costs for the irrigated fertility experiments at Chickasha are given in Table XIV.

In 1958, the 80 pounds of nitrogen and 80 pounds of phosphorus treatment gave the highest net returns. However, the additional costs for most treatments are greater than the additional returns. The 1958 data do not conform with the expected model.

In 1959 and 1960, 80 pounds of nitrogen combined with 40 pounds of phosphorus resulted in the highest net returns. The 1959 and 1960 data

TABLE XIII

COTTON FERTILITY TEST ON IRRIGATED HOLLISTER SILTY CLAY LOAM SOIL AT ALTUS, OKLAHOMA, 1961

	- Nitrogen -							
	0		40		80		160	
Phosphorus	Yield	Returns Above Ferti- lizer Costs[a]	Yield	Returns Above Ferti- lizer Costs[a]	Yield	Returns Above Ferti- lizer Costs[a]	Yield	Returns Above Ferti- lizer Costs[a]
	- Per Acre -							
Pounds	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
0	727	0.00	--	--	1042	46.30	--	--
40	--	--	990	34.14	1058	45.18	1135	48.64*
80	663	-19.52	1028	40.98	1037	37.40	1105	39.24
160	--	--	--	--	1104	41.46	--	--

*Highest net returns for individual year.

[a]Returns above fertilizer costs were computed in each year by subtracting the returns for the check plot from the returns (after fertilizer costs were paid) for each of the other treatments. The following prices were assumed:

(1) Nitrogen - $.13 per lb.
(2) Phosphorus - $.10 per lb.
(3) Harvesting and marketing costs on additional yield - $.10 per lb.
(4) Cotton lint - $.28 per lb.

TABLE XIV

COTTON FERTILITY TEST ON IRRIGATED McLAIN SILTY CLAY LOAM SOIL AT CHICKASHA, OKLAHOMA, 1958-1960

		- Nitrogen -									
		0		40		80		120		160	
Year	Phosphorus	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]
		- Per Acre -									
	Pounds	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
1958	0	877	0.00	--	--	879	-10.04	--	--	--	--
	40	--	--	723	-36.92	828	-23.22	--	--	976	-6.98
	80	936	2.62	924	-4.74	1010	5.54*	--	--	961	-13.68
	160	--	--	--	--	808	-38.82	--	--	866	-38.78
1959	0	958	0.00	--	--	936	-14.36	--	--	--	--
	40	--	--	971	-6.86	1061	4.14*	--	--	1056	-7.16
	80	970	-5.84	999	-5.82	1032	-5.08	--	--	1036	-14.76
	160	--	--	--	--	979	-22.62	--	--	997	-29.78
1960	0	937	0.00	--	--	964	-5.54	--	--	--	--
	40	--	--	929	-10.64	1064	8.46*	--	--	1069	-1.04
	80	935	-7.64	997	-2.40	1047	1.40	--	--	978	-21.42
	160	--	--	--	--	1003	-14.52	--	--	1015	-22.76
1961	0	[b]	0.00	--	--	985	-6.80	--	--	--	--
	20	--	--	--	--	1024	-1.78	--	--	--	--
	40	--	--	--	--	992	-9.54	--	--	1049	-9.68
	80	980	-5.30	982	-10.14	1049	-3.28	1006	-16.22	980	-26.10
	160	--	--	--	--	1120	1.50*	--	--	994	-31.58

TABLE XIV (Continued)

		Nitrogen 0		Nitrogen 40		Nitrogen 80		Nitrogen 120		Nitrogen 160	
Year	Phosphorus	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]	Yield	Returns Above Fertilizer Costs[a]
		- Per Acre -									
	Pounds	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Average	0	924[c]	0.00[c]	--	--	941	-7.34	--	--	--	--
	20	--	--	--	--	1024[d]	5.60	--	--	--	--
	40	--	--	874[c]	-18.20	986.2	-3.20	--	--	1037.5	-4.37
	80	955.2	-2.38	975.5	-3.93	1034.5	1.49*	1006[d]	-8.84	988.8	-17.14
	160	--	--	--	--	977.5	-16.77	--	--	968.0	-28.88

*Highest net returns for individual year or four-year average.

[a]Returns above fertilizer costs were computed in each year by subtracting the returns for the check plot from the returns (after fertilizer costs were paid) for each of the other treatments. The following prices were assumed:

(1) Nitrogen - $.13 per lb.
(2) Phosphorus - $.10 per lb.
(3) Harvesting and marketing costs on additional yield - $.10 per lb.
(4) Cotton lint - $.28 per lb.

[b]The yield for no fertilizer was not recorded in 1961, but in computing additional net returns, the base yield was considered to be 965 pounds per acre.

[c]Average of three years.

[d]Only one year of data available.

conformed fairly well with the expected model. The sub-production functions with: (1) P = 40, (2) P = 80, and (3) N = 80, agreed exceptionally well with the expected model.

In 1961, the highest net returns were obtained from a treatment of 160 pounds of phosphorus and 80 pounds of nitrogen. The 1961 data were compatible with the expected model, but the yield for 80 pounds nitrogen and 40 pounds phosphorus was lower than expected.

The 80 pounds of nitrogen and 80 pounds of phosphorus treatment resulted in the highest net returns for the four-year average. The sub-production functions where P = 40 and P = 80 agreed with the expected model, but 80 pounds nitrogen and 40 pounds phosphorus was lower than expected.

With the prices assumed in this chapter, the results of this experiment seem to suggest that some undetermined level of phosphorus with 80 pounds of nitrogen probably will increase net returns slightly. However, the proper level of phosphorus appeared to depend on the type of year.

Production Functions

Equations for estimating yield levels from different rates of nitrogen and phosphorus were developed by least squares regression.

Dryland Fertility Experiments

Mangum:

The production equations for the dryland fertility experiment at Mangum are presented in Table XV. Individual year equations explain a large percentage of the variation. However, some of the regression coefficients have a high probability of being zero. Equations were fitted

TABLE XV

COTTON FERTILITY TEST ON DRYLAND BROWNFIELD LOAMY SAND AT MANGUM, OKLAHOMA

Years Covered By Data	Level of Nutrient for Maximum N.R.[a] Pounds Per Acre	d.f.	R^2	The Regression Equation
1959		6	.72	$Y = 352.133 + \overset{.36}{2.965N} - \overset{>.40}{.0154N^2} + \overset{>.40}{2.635P} - \overset{>.40}{.0650P^2} + \overset{>.40}{.0005NP}$
1960	N = 228.2[b,c]	6	.97	$Y = 526.683 + \overset{.04}{6.776N} - \overset{>.40}{.0160N^2} + \overset{>.40}{2.805P} - \overset{.36}{.0850P^2} + \overset{.184}{.06252NP}$
1961		7	.86	$Y = 366.742 + \overset{.02}{9.327N} - \overset{.35}{.0462N^2} + \overset{.18}{6.884P} - \overset{>.40}{.0474P^2} - \overset{>.40}{.0627NP}$
1959-61	N = 91.6[b,d]	34	.40	$Y = 434.657 + \overset{.02}{7.427N} - \overset{.33}{.0366N^2}$

[a]Assuming the following prices:
(1) Nitrogen - \$.13 per lb.
(2) Phosphorus - \$.10 per lb.
(3) Harvesting and marketing costs on additional yield - \$.10 per lb.
(4) Cotton lint - \$.28 per lb.

[b]An extrapolation.

[c]Assuming P = 20.

[d]Phosphorus was allowed to take on all values used in the experiment (0,20,40,60).

across years with nitrogen and phosphorus as independent variables, but the coefficients of the phosphorus terms had a high probability of being zero. Therefore, only nitrogen was included in the across years equation in Table XV, and phosphorus was allowed to take on all of the values included in the experiment (i.e., phosphorus treatments were assumed to be the same). The across years equation indicated that net returns were a maximum when 91.6 pounds of nitrogen were applied per acre. However, this was an extrapolation and not much confidence should be placed in this figure because only one observation has been made in this experiment when nitrogen was applied at a rate above 80 pounds per acre. For this reason, the discrete method indicated that 60 pounds of nitrogen (the highest rate tested in two of the three years) combined with 20 pounds of phosphorus produced the highest net returns.

Phosphorus was set at 20 pounds per acre in the 1960 equation and the optimum nitrogen was determined to be 228.2 pounds per acre. This points out that more experiments with larger applications of nitrogen are needed before a conclusion can be reached as to the most profitable rate of fertilization at the Sandy Land Research Station at Mangum.

Chickasha:

The production equations for the dryland fertility experiment at Chickasha are given in Table XVI. The coefficients in these equations have a high probability of being zero. As indicated earlier, the results from the fertilizer treatments in this experiment have been very erratic and inconclusive.

TABLE XVI

COTTON FERTILITY TEST ON DRYLAND REINACH SILT LOAM SOIL AT CHICKASHA, OKLAHOMA

Years Covered By Data	d.f.	R^2	The Regression Equation					
				.21	.16	.31	.24	>.40
1958	6	.55	$Y = 517.656$	$- 4.124N$	$+ 38.032\sqrt{N}$	$- 5.331P$	$+ 39.970\sqrt{P}$	$- 1.623\sqrt{NP}$
				>.40	>.40	.28	.28	>.40
1959	6	.36	$Y = 446.508$	$- .356N$	$+ 3.001\sqrt{N}$	$+ 4.786P$	$- 27.390\sqrt{P}$	$- .0129NP$
				.36	>.40	.31	>.40	.21
1960	6	.49	$Y = 558.132$	$+ 1.634N$	$- 7.203\sqrt{N}$	$+ 3.093P$	$- 11.070\sqrt{P}$	$- .0385NP$
				>.40	.21	>.40	>.40	.16
1961	7	.59	$Y = 532.573$	$- .263N$	$+ 9.939\sqrt{N}$	$+ 1.200P$	$- 2.999\sqrt{P}$	$- 1.234\sqrt{NP}$
				>.40	>.40	>.40	>.40	>.40
1958-61	43	.026	$Y = 514.771$	$- .657N$	$+ 9.940\sqrt{N}$	$+ .751P$	$+ .514\sqrt{P}$	$- 1.098\sqrt{NP}$

Irrigated Fertility Experiments

Altus:

A square root production equation for the 1961 irrigated fertility experiment is presented in Table XVII. Only the equation with the highest R^2 and most significant coefficients is presented. The equation was derived assuming phosphorus treatments were equal. The equation explains 97 percent of the variation in the data. The coefficients of N and $\sqrt{N}$ have a probability of .18 and .02, respectively, of occurring by chance alone.

The production function method indicated that net returns will be maximized when 107 pounds of nitrogen per acre were applied. The discrete model demonstrated that net returns were about the same for 80 and 160 pounds of nitrogen per acre; thus, the two methods agree.

Chickasha:

Some of the production equations developed from the irrigated cotton fertility experiments at Chickasha are given in Table XVIII. These equations do not score well on the statistical tests. Many of the regression coefficients were not significantly different from zero at the ten percent level. From the equation for 1958-61, it was determined that net returns were a maximum when 24 pounds of nitrogen and 39 pounds of phosphorus were applied per acre. This differed considerably from the figures (80 pounds of nitrogen and 80 pounds of phosphorus) obtained for the average by use of the discrete model.

In an effort to determine the influence fertilizer had on the yield of irrigated cotton at Chickasha, several equations were developed. Some of the equations which scored fairly well on the statistical tests are

TABLE XVII

COTTON FERTILITY TEST ON IRRIGATED HOLLISTER SILTY CLAY LOAM SOIL AT ALTUS, OKLAHOMA

Years Covered By Data	Level of Nutrient for Maximum N.R.[a] Pounds Per Acre	d.f.	R^2	The Regression Equation
1961	N = 107[b]	7	.97	.18 .02 $Y = 696.825 - 2.258N + 61.670 \sqrt{N}$

[a]Assuming the following prices:

(1) Nitrogen - $.13 per lb.
(2) Phosphorus - $.10 per lb.
(3) Harvesting and marketing costs on additional yield - $.10 per lb.
(4) Cotton lint - $.28 per lb.

[b]Phosphorus was allowed to take on all values used in the experiment (0,40,80,160).

TABLE XVIII

COTTON FERTILITY TEST ON IRRIGATED McLAIN SILTY CLAY LOAM SOIL AT CHICKASHA, OKLAHOMA

Years Covered By Data	Level of Nutrient for Maximum N.R.[a] Pounds Per Acre	d.f.	R^2	The Regression Equation
1958		5	.38	$Y = 860.59 + \overset{.36}{3.522N} - \overset{>.40}{30.425\sqrt{N}} + \overset{>.40}{1.045P} + \overset{>.40}{.319\sqrt{P}} - \overset{>.40}{.0135NP}$
1959		5	.78	$Y = 951.65 + \overset{>.40}{.203N} - \overset{>.40}{2.836\sqrt{N}} + \overset{.10}{1.760P} + \overset{.12}{17.779\sqrt{P}} + \overset{>.40}{.725\sqrt{NP}}$
1960		5	.53	$Y = 912.72 + \overset{.36}{1.534N} - \overset{>.40}{.00533N^2} + \overset{>.40}{.573P} - \overset{>.40}{.00256P^2} - \overset{>.40}{.00161NP}$
1961		5	.83	$Y = 842.37 + \overset{.07}{2.432N} - \overset{.32}{.00527N^2} + \overset{.32}{1.080P} + \overset{.25}{.00690P^2} - \overset{.06}{.0179NP}$
1958-61	N = 24 P = 39	39	.15	$Y = 902.65 + \overset{.26}{.844N} - \overset{>.40}{.00256N^2} + \overset{.18}{1.018P} - \overset{.17}{.00593P^2}$

[a]Assuming the following prices:

(1) Nitrogen - \$.13 per lb.
(2) Phosphorus - \$.10 per lb.
(3) Harvesting and marketing costs on additional yield - \$.10 per lb.
(4) Cotton lint - \$.28 per lb.

presented in Table XIX. These equations were developed by using only the observations with one nutrient at a predetermined level and allowing the other nutrient to vary. It can be seen that the quality of these equations is considerably better than the equations presented in Table XVIII. These results emphasize the need for further long-term experiments because a response to the nutrients is obtained in some years under some conditions.

Summary

Data from four fertility experiments were analyzed by two methods in this chapter.

Results of the analysis for Mangum suggest that on the average, net returns increased as the nutrients were added up to 60 pounds per acre and possibly 90 pounds per acre of nitrogen and 20 pounds per acre of phosphorus. More experiments with larger applications of nitrogen are needed before a definite conclusion can be reached as to the most profitable rate of fertilization at the Sandy Land Research Station near Mangum.

The profitability of fertilizing dryland cotton on Reinach silt loam soil near Chickasha was questionable.

The 1961 results for the irrigated cotton experiment at Altus, indicated that net returns were maximized when approximately 100 pounds per acre of nitrogen were applied.

Further long-term experiments are needed on irrigated cotton near Chickasha because a response to the nutrients is obtained in some years under some conditions.

TABLE XIX

COTTON FERTILITY EQUATIONS, WITH ONE NUTRIENT HELD CONSTANT, FOR IRRIGATED McLAIN SILTY CLAY LOAM SOIL AT CHICKASHA, OKLAHOMA

Years Covered By Data	Level of Other Added Nutrients	Level of Nutrient for Maximum N.R.[a] Pounds Per Acre	d.f.	R^2	The Regression Equation
1958	P = 80		1	.45	$Y = 921.96 + \overset{>.40}{1.226N} - \overset{>.40}{.00595N^2}$
1959	P = 80		1	.98	$Y = 967.98 + \overset{.126}{1.070N} - \overset{.193}{.004N^2}$
1960	P = 80		1	.98	$Y = 931.37 + \overset{.10}{2.410N} - \overset{.107}{.0132N^2}$
1961	P = 80		2	.29	$Y = 975.30 - \overset{>.40}{0.747N} + \overset{>.40}{10.789\sqrt{N}}$
1958-61	P = 80	N = 49.7	14	.47	$Y = 948.19 + \overset{.006}{1.478N} - \overset{.014}{.00760N^2}$
1958-61	N = 80	P = 64.1	14	.14	$Y = 942.82 + \overset{.156}{1.902P} - \overset{.183}{.0105P^2}$

[a]Assuming the following prices:

(1) Nitrogen - $.13 per lb.
(2) Phosphorus - $.10 per lb.
(3) Harvesting and marketing costs on additional yield - $.10 per lb.
(4) Cotton lint - $.28 per lb.

CHAPTER IV

INSECT CONTROL

Problem Setting

The cotton insect problem in Oklahoma has baffled farmers and researchers for some time. It has been estimated that in 1960 bollworms alone caused more than $4.5 million damage in Oklahoma. It was also estimated that this figure accounted for only 36 percent of the total insect loss during that year.[1] These figures illustrate the importance of the cotton insect problem.

The cotton insect problem is especially complex because:

(1) Many different combinations of nature can exist (states of nature).

(2) Numerous alternative control strategies are available to the farm manager.

Further discussion of the problem will be considered under the above categories.

States of Nature

Many different combinations of nature can exist, but the probability of each combination is unknown. This phenomenon gives rise to a state

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[1] D. E. Bryan, "Cotton Insect Control in Oklahoma," Oklahoma State University Agricultural Experiment Station Processed Series P-396, December, 1961, p. 6.

of uncertainty.[2] Many insects damage cotton and any one of any combination of these insects may exist in a field at any level of infestation.

Some insects are resistant to common insecticides while others are easily controlled. It is usually impossible to distinguish between resistant and susceptible insects and sometimes only an expert can distinguish between the different species of insects. For example, it is very difficult to differentiate between the cotton bollworm and the tobacco budworm.

Insect infestation levels vary, and determining the level of infestation in the future is extremely difficult because unpredictable factors such as weather, crop conditions, diseases, predators, and parasites influence insect migration, reproduction, and mortality.

From the above discussion, it is evident that many combinations of nature do exist, and uncertainty appears to be the most prevalent attribute of the cotton insect problem.

Farmers' Control Strategies

Numerous alternative strategies are available to the farm manager. The farm manager may choose to control or ignore cotton insects. If the farm manager decides that control is necessary, he has several alternatives as to the kind, amount, concentration, and form (spray or dust) of insecticide to use. The equipment to be used and the interval between applications are two more variables which the farmer must consider. Many of these variables actually exist as continuous functions;

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[2]See Chapter I, pages 7-8, for a discussion of the states of knowledge.

therefore, the combinations of these variables are infinite. But the farmer faces the difficult problem of choosing the single combination which is optimum for the state of nature which he faces, even though he is not sure what the state of nature actually is or will be.

Available Information

The extension service is distributing helpful insect control information such as that given in Table XX. However, this information is inadequate because the recommendations are

(1) based upon infestation counts and average conditions, and

(2) made considering only one goal of farmers. Farm managers seldom have average conditions for all the attributes of nature. Many farmers probably have goals other than the one which was considered in the recommendations.

A great deal of research has been done which is not contained in Table XX. Some of the results of past entomology research are given in outline form below.

General

(1) "Cotton insect populations in Oklahoma are characterized by sharp fluctuations which are related mainly to climatic variability."[3]

(2) Research indicates that rain and/or wind reduce the effectiveness of most insecticides.[4]

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[3] Bryan, p. 10.

[4] See B. G. Hightower and J. C. Gaines, "Residual Toxicities of Insecticides to Cotton Insects," Texas Agricultural Experiment Station Bulletin 951, March, 1960, for a discussion of the effects of climatic variables on the residual toxicities of insecticides.

TABLE XX

COTTON INSECT CONTROL RECOMMENDATIONS FOR

Oklahoma 1962

INSECTS	CONTROL WITH DUSTS: Insecticide	CONTROL WITH DUSTS: Pounds Mixture Per Acre	CONTROL WITH SPRAYS: Insecticide	CONTROL WITH SPRAYS: Pounds Technical Per Acre	APPLICATION INFORMATION
Boll Weevil Any one of the controls listed.	3% gBHC-10% DDT-40% Sulfur or 20% Toxaphene 40% Sulfur or 2.5% Aldrin-5% DDT-40% Sulfur or 2.5% Heptachlor 5% DDT-40% Sulfur or 7.5% Sevin or 20% Malathion-10% DDT or 2.5% Methyl Parathion-10% DDT or 2.5% Guthion-10% DDT or 2.5% Dieldrin-5% DDT-40% Sulfur	10-15 10-15 10-15 10-15 15-30 10-15 10-20 10-20 10-15	Toxaphene } DDT or Toxaphene or Aldrin } DDT or Dieldrin } DDT or Heptachlor } DDT or Endrin or Sevin Sprayable* or Malathion } DDT or Methyl Parathion } DDT or Guthion } DDT	2.0 / 1.0 2.0-3.0 0.25-0.5 / 1.0 0.25-0.5 / 1.0 0.25-0.5 / 1.0 0.2-0.5 1.0-2.0 2.0 / 1.0-1.5 0.25-0.5 / 1.0-2.0 0.25-0.5 / 1.0-2.0	Treat when 25% of squares are punctured. Repeat at 3 to 4 day intervals until infestation drops. DDT should be omitted where bollworms are not a problem.
In areas where boll weevils are resistant to the chlorinated hydrocarbon materials use one of the materials listed here.	7.5% Sevin or 20% Malathion-10% DDT or 2.5% Methyl Parathion-10% DDT or 2.5% Guthion-10% DDT	15-30 10-15 10-20 10-20	Sevin Sprayable* or Malathion } DDT or Methyl Parathion } DDT or Guthion } DDT	1.0-2.0 2.0 / 1.0-1.5 0.25-0.5 / 1.0-2.0 0.25-0.5 / 1.0-2.0	
Bollworms	10% DDT or 7.5% Sevin	15-20 25-30	DDT or Endrin or Sevin Sprayable*	1.5-2.0 0.2-0.5 2.0	Treat when eggs and 5 small bollworms are found per 100 plants. When necessary repeat at 5 to 7 day intervals.
Cabbage Looper	2% Endrin	25	Endrin	0.5	Apply insecticide while loopers are small.
Cotton Leafworm	20% Toxaphene-40% Sulfur or 2% Endrin or 4% Malathion or 1% Parathion	10 10-25 7-15 15-25	Toxaphene } DDT or Toxaphene or Endrin or Malathion or Parathion	2.0 / 1.0 2.0 0.2-0.5 0.25-0.5 0.125-0.25	Treat when first "ragging" appears, or 2-5 larvae per plant.
Cotton Fleahopper	3% gBHC-10% DDT-40% Sulfur or 20% Toxaphene-40% Sulfur or 2.5% Aldrin or 2.5% Dieldrin or 2.5% Heptachlor or 10% DDT	7-10 5 10 5 10 5	Toxaphene } DDT or Toxaphene or Aldrin } DDT or Dieldrin } DDT or Heptachlor } DDT or Endrin or DDT	1.0 / .5 0.75-1.0 0.25 / 0.5 0.1-0.15 / 0.4-0.6 0.25 / 0.5 0.1-0.2 0.5	Treat when 15-35 fleahoppers are found per 100 terminals. DDT should be omitted where bollworms are not a problem.
Grasshoppers	20% Toxaphene-40% Sulfur or 2.5% Aldrin or 2.5% Dieldrin or 2.5% Heptachlor	5-15 5-10 3-5 10-20	Toxaphene or Aldrin or Dieldrin or Heptachlor	1.0-2.5 0.1-0.25 0.07-0.125 0.25-0.5	Treat field margins adjacent to fence rows, ditch banks, turn rows, roadsides or other weedy areas when insects first appear.
Cotton Aphid	1% Parathion or 4% Malathion	10-25 15-25	Malathion or Demeton (Systox) or Methyl Parathion or Ethyl Parathion or Ethion	0.5-1.0 0.125-0.4 0.25-0.5 0.10-0.25 0.5-1.0	Treat when honeydew first appears.
Spider Mites	3% Aramite or 4% Malathion or 1% Parathion	15-30 10-20 10-40	Aramite or Malathion or Demeton (Systox) or Parathion or Ethion	0.33-1.0 0.25-0.75 0.125-0.4 0.1-0.4 0.5-1.0	Treat when infestation averages 25 mites per leaf.

*Sevin is available as a sprayable (similar to the w.p. of the insecticides). Care should be taken to use no finer than 50 mesh screens when Sevin Sprayable is being used.

Source: "Official 1962 Cotton Pest Control Guides," National Cotton Council, Memphis, Tennessee, 1962, p. 19.

(3) Treatment of seed before planting may increase the net effectiveness of some insecticides because beneficial insects will not be harmed.

(4) Early season control is not economically feasible in Oklahoma because:

  (a) Early season insects are not a problem in Oklahoma every year.

  (b) Thrips delay maturity, but apparently do not decrease yield.

  (c) Bollweevils come out of hibernation over too long of a period of time.

  (d) Fleahoppers spend the winter in the egg stage and cannot be killed until they hatch.

  (e) Early season control kills beneficial insects and probably makes it necessary to use bollworm insecticides earlier.

Bollweevil

(1) Reproduction rates decrease when weather is hot and dry.

(2) No predator or parasitic insects attack bollweevil.

(3) Some bollweevils are resistant to particular chemicals.

(4) To be effective on bollweevil, insecticide must be applied every 3 to 4 days.

(5) Bollweevils may migrate up to 50 miles in a few days.

(6) Bollweevils hibernate in woods, trash, fence rows, grass, etc.

Bollworm

(1) Apparently temperature has little effect on the reproduction rate of bollworms.

(2) Reproduction rates decrease when the plant is not succulent.

(3) The cotton bollworm and the tobacco budworm are common in Oklahoma and are difficult to tell apart. The tobacco budworm is very difficult to control.

(4) Many predator insects attack bollworm eggs and larvae. Field spider and lace-winged fly larvae are the two most important.

(5) Bollworms feed on corn, legumes, or sorghum, early in season, then migrate to cotton.

(6) Tobacco budworms are not known to attack corn or sorghum.

Fleahopper

(1) The fleahopper is not a constant threat.

(2) Heavy infestations of fleahoppers must be controlled because they are toxic to plants and make tiny squares fall off.

(3) Several predator insects attack fleahoppers.

(4) Fleahoppers migrate from horsemint to cotton.

Cabbage Looper

(1) It is not known when infestation counts are high enough to warrant application of insecticides.

(2) Endrin is the only effective insecticide for cabbage looper.

(3) Control is unlikely on large loopers.

(4) Cabbage loopers attack cabbage, lettuce, beets, potatoes, tomatoes, and several other plants.

Leafworm

(1) Infestations always originate from flights of moths from Central America because leafworms cannot survive the winter in any part of the United States; therefore, leafworms seldom reach Oklahoma early enough to damage cotton.

(2) Cotton leafworms are only known to reproduce on cotton.

Cotton Aphids

(1) Cotton aphids are controlled with hard rain.

(2) Damage from cotton aphids is more likely in cool, damp weather.

Spider mites

(1) Spider mites are controlled with hard rain.

Beneficial insects[5]

(1) Predators and parasites are the two kinds of beneficial insects.

(2) Beneficial insects attack eggs and larvae of:

(a) bollworm

(b) leafworms

(c) aphids

(d) mites

(e) other soft bodied insects

(f) fleahoppers.

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[5]See J. C. Gaines, "Cotton Insects," Texas Agricultural Extension Service Bulletin 933, June, 1959, for a more complete discussion of beneficial insects.

A review of the information given in the above outline reveals that levels of infestation depend on many variables such as weather, diseases, predators, and parasites, which influence reproduction and death rates. Further examination of the outline indicates that general information is known about these variables, but the exact influence these variables have on the optimum production strategy is not known. For example, apparently reproduction rates of bollworms decrease as the plant becomes less succulent; however, the amount of reduction in reproduction rates is not known. Also, it is known that beneficial insects kill a large number of harmful insects; however, the relationship between the number of beneficial insects present and the decrease in the number of harmful insects is not known.

Factors other than infestation levels are probably considered collectively as average conditions because the exact influence each of the factors has on the optimum production strategy probably is not known.

In summary, present insect control information is helpful but inadequate because the recommendations

(1) are based upon infestation counts while the other variables are considered collectively as average conditions, and

(2) consider only one managerial goal.

Average conditions for all the attributes of nature are seldom present, and many farm managers probably have goals other than the one which was considered in the recommendations.

Thus, it would be extremely helpful if a technique could be derived which would take into account attributes of nature in uncertainty situations.[6] An approach utilizing game theory in analyzing the insect problem is developed in the following analytical technique section.

Analytical Techniques

Sample applications of two game criteria are presented in this section: (1) maximum security level, and (2) minimum regret.

The maximum security level is obtained by using the maximin strategy. That is, the manager chooses the strategy that has the greatest minimum net returns. For example, assume a farmer's cotton is being damaged by bollweevils. He knows that some of the bollweevils in the county are resistant to the insecticides commonly used; however, he doesn't know if his bollweevils are resistant or not. The farmer realizes a new insecticide has been successful on the resistant weevils, but it is more expensive. This farmer wants to maximize the security level. Which insecticide should he use to attain his goal?

This problem might be thought of as a game against nature. Suppose that the manager's alternative strategies (common insecticide, new insecticide) are represented by X_{11} and X_{12}. The states of nature (resistant bollweevil, nonresistant bollweevil) are represented by X_{21} and X_{22}. Each interaction between X_{1i} and X_{2j} results in a level of

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[6] See Odell L. Walker, Earl O. Heady, Luther G. Tweeten, and John T. Pesek, "Application of Game Theory Models to Decisions on Farm Practices and Resource Use," Iowa State University Agricultural and Home Economics Experiment Station Research Bulletin 488, December, 1960, for a more complete discussion of the application of game theory.

net returns (NRij). This information may be arranged in a matrix such as the following:[7]

	Resistant X_{21}	Nonresistant X_{22}
Common Insecticide X_{11}	20	40
New Insecticide X_{12}	30	25

For this example X_{12} is the optimum pure strategy according to the maximin criterion because 25 is the greatest security level. A mixed strategy (a combination of X_{11} and X_{12}) will yield a greater security level because 25, the minimum in row X_{12} is not the maximum in column X_{22}. That is, using the new insecticide on part of the cotton, and using the common insecticide on the remainder of the cotton will give a higher security level. The proportion of X_{11} and X_{12} may be determined as follows:

If X_{21} occurs,

$$NR = 20P_1 + 30P_2 \tag{4.1}$$

If X_{22} occurs,

$$NR = 40P_1 + 25P_2 \tag{4.2}$$

The sum of the parts (P_1 and P_2) must equal a whole.

$$P_1 + P_2 = 1 \tag{4.3}$$

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[7]The matrices, production functions, and budgeting techniques used in this study imply a unique outcome (NRij) for each state of nature--production strategy combination. However, there will usually be a distribution of outcomes for each state of nature--production strategy combination. Throughout this thesis, the net returns obtained (as well as the physical data used) are assumed to be statistically different at an acceptable probability level, i.e., the confidence limits do not overlap.

Simultaneous solution of (4.1), (4.2), and (4.3) gives $P_1 = 1/5$ and $P_2 = 4/5$. Using X_{11} and X_{12} in these proportions gives NR = 28 whether X_{21} or X_{22} prevails. Thus, with this information the manager can decide if it is worthwhile for him to use some of each kind of insecticide.[8]

If the probability distribution of outcomes is or becomes known, i.e., if X_{21} and X_{22} will occur with a known probability, the manager may still wish to maximize the security level. In the previous example, the probability distribution might become known if entomologists performed a survey or experiment in the community and found that a given percentage of the fields were infested with resistant bollweevil. Suppose, the entomologists found that .4 of the fields were infested with resistant bollweevil. The previous matrix becomes

	X_{21}(.4)	X_{22}(.6)	E(NR)[9]
X_{11}	20	40	29
X_{12}	30	25	27
$1/5X_{11} + 4/5X_{12}$	28	28	28

Thus, in the above hypothetical example, if the manager chooses to maximize security level rather than expected NR, he can expect NR to be two less for a pure strategy or one less for the best mixed strategy.

[8]Using a mixed strategy probably would not be practical in the example cited unless the fields are separated. Thus, discouraging migration if the resistant bollweevils are present.

[9]Expected NR are obtained by using the following equation:

$$E(NR) = P_y \left[\sum_{j=1}^{m} P_j \, f(X_1, X_2)_j \right] - P_{xi} X_i$$

Many times farmers' actions seem to indicate that they change goals during the crop season. For example, farmers may ignore cotton insects until late in the season. After the insects have done most of their damage, the farmer may begin applying insecticides, apparently trying to save enough crop to pay variable costs. This problem is beyond the scope of this study; however, it is hypothesized that the loss in net returns is very great when the goal is changed during the crop season.

Some farm managers' actions relating to the cotton insect problem seem to indicate a goal of minimum regret. For example, several Oklahoma farmers practice early season insect control,[10] even though research indicates that it is not economically feasible in Oklahoma. Other farmers have insecticides applied every five or seven days without regard to infestation levels. Several managers follow these practices, perhaps reasoning that if they do use insecticides throughout the crop season and their cotton isn't damaged, their regret will be the cost of the insecticide. If they don't continuously use insecticides and the insects get too large to control,[11] their regret will be the difference between the cost of the insecticides and value of the crop lost.

The minimum regret criterion will now be illustrated with an example. Assume last year cabbage loopers damaged a farmer's irrigated cotton so severely that his net returns were equal to -\$70 per acre.

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[10]Early season insect control refers to the practice of applying insecticides two to four times at five to seven day intervals early in the season <u>every year</u>. These applications are made without regard to infestation levels. Oklahoma research indicates that early season control is not economically feasible because the insects are not always present when the application is made.

[11]Many cotton insects are more easily controlled when small. For example, insecticides are ineffective on large cabbage loopers.

Entomologists have informed the farmer about three important characteristics of cabbage loopers.

(1) Loopers very seldom damage cotton in his area.

(2) Insecticides are ineffective on large loopers.

(3) When loopers do attack their damage can be very severe.

The farmer's regret for last year is very great and he wants to minimize regret in the future by using one of the following strategies:

(1) Apply insecticides every five days during the crop season.

(2) Apply insecticides after damage begins to appear.

Each combination of farmer strategies and the various states of nature each result in some net returns. This information can be summarized in a matrix such as the following:

		No Loopers	Loopers Attack
		X_{21}	X_{22}
Apply insecticides every five days	X_{11}	40	40
after damage appears	X_{12}	100	-70

A regret matrix can be formed by subtracting the maximum net returns in each column from each net return in that column.

The above matrix can be transformed into the following regret matrix:

		No Loopers	Loopers Attack
		X_{21}	X_{22}
Apply insecticides every five days	X_{11}	-60	0
after damage appears	X_{12}	0	-110

The negative entries (Rij) represent the cost of having followed the wrong strategy for the realized state of nature. The farmers regret varies directly as the absolute value of the Rij. When Rij = 0, the farmer has no regret. For this example, X_{11} is the optimum pure strategy. However, when the regret criterion is used, a mixed strategy (if possible) will always be preferred to a pure strategy because the minimum regret in the column will never be the maximum regret in the row. In this example, a mixed strategy of $11/17\ X_{11} + 6/17\ X_{12}$ gives a regret level of approximately -39 which is less in absolute value than -60, the regret for the best pure strategy X_{11}.

Suggestions for Future Research

The entire cotton insect problem could be analyzed in a manner similar to the preceding examples. The matrix for each managerial goal for the entire cotton insect problem would be larger than 100 by 100; however, these matrices could be analyzed through the use of linear programming techniques.[12]

The various states of nature to be considered in the general cotton insect problem includes all combinations of the following:

(1) Species of each insect (bollweevil, bollworm, etc.),

(2) Kind of insect (resistant or susceptible),

(3) Various levels of infestations,

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[12] The various states of nature and managerial goals, which are continuous functions would need to be considered at discrete levels with small intervals between the levels considered.

(4) Weather variables[13] (rain, wind, cool, hot, etc.),

(5) Condition of cotton (succulent, tough, etc.),

(6) Migration habits,

(7) Number of predators,

(8) Diseases of each type of insect,

(9) Surrounding crops or foliage and their condition.

It is possible that some of the above characteristics of the state of nature could be combined and others might be added, but at the present time it is thought that these are the most important variables to be considered.

Farmers' alternative strategies would include all combinations of the following variables:

(1) Kinds of insecticides,

(2) Amounts of insecticide,

(3) Time during season when application is made,

(4) Frequency of application,

(5) Form of insecticide (spray or dust),

(6) Equipment used to apply insecticide,

(7) Concentration of insecticide.

Recent research indicates that some of the above variables have little effect (within certain limits) on the control of insects; therefore, those variables might be ignored.

Net returns (NRij) for the interaction of each farmer strategy and state of nature must be known to use the game model suggested.

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[13]See Hightower and Gaines for a complete discussion on the effect various weather variables have on insecticides.

Unfortunately, obtaining information from experiment stations is slow because fund and time limitations simply do not allow all states of nature to be examined. However, the author believes that this information could be obtained from farmers.

Cotton farmers experience many different states of nature (X_{2_j}), follow numerous production strategies (X_{1_i}), and obtain various net returns (NRij). As pointed out previously, this is the information which researchers need to solve the insect problem. The solution to the insect problem hinges on obtaining information regarding states of nature, production strategies, net returns from farmers. A procedure for obtaining and using this information is outlined below.

(1) Educate the farmers in the cotton producing area about the information needed and about how they can help solve the insect problem. This educational program might be performed by county agents and vocational agricultural teachers having one or two meetings with farmers in their area.

It was mentioned at the first of this chapter that insects are doing several million dollars damage in Oklahoma each year; therefore, it seems reasonable to think that farmers will be willing to help in a useful information gathering program.

(2) Ask selected farmers to send in comprehensive weekly or semi-weekly reports of the state of nature experienced and the production strategy followed. These reports could include the following:

<u>States of Nature</u>

(a) Date

(b) Species of insect

(c) Level of infestation of each insect

(d) Weather variables (rain, wind, temperature, etc.)

(e) Condition of cotton (age, succulent, tough, etc.)

(f) Number and species of beneficial insects

(g) Surrounding crops or foliage and their condition

Farmer's Strategies

(a) Insecticide used, if any

(b) Concentration of insecticide

(c) Amount of insecticide

(d) Form of insecticide (spray or dust)

(e) Time during season when application is made

(f) Interval of application

(g) Equipment used to apply insecticide

It will be necessary to train farmers to obtain and report the above information. The information will likely be reported in such a manner that it can be analyzed quickly with a computer. It is possible that each farmer will need to buy a small amount of equipment such as a rain gauge, a thermometer, a wind gauge, and possibly a barometer. This briefing might be combined with step 1.

(3) Analyze the above information and attempt to determine the influence the production strategies have had on the state of nature.

(4) Summarize and send results of step 3 to the participating farmers as soon as possible. These results should be sent to the participating farmers weekly so that they may benefit from the knowledge of

the production strategies of the other farmers. These weekly reports sent to the farmers should encourage participation.

(5) Each farmer will report the yield, grade, and staple resulting from his production strategies.

(6) Assign prices to the physical data obtained from steps 1-5, and determine the net returns for the elements of the states of nature-production strategies matrix.

(7) Use game theory (similar to that outlined in the analytical technique section) to analyze the alternative production strategies for various managerial goals.

The knowledge obtained from the above procedure combined with an improvement in weather forecasting, which is expected from weather satellites, will likely go a long way toward solving the cotton insect problem.

The author realizes that several years of data are needed to carry out the forenamed program, but apparently no shorter route has been discovered.

Summary

Game theory was introduced and developed for analyzing the insect problem and considering various managerial goals. Physical data are not available at the present time for using game theory; however, a procedure was outlined for obtaining the needed information from farmers.

CHAPTER V

MECHANICAL HARVESTING

Problem Setting

Mechanical harvesting is one of the most important and popular technological developments in cotton production. Many Oklahoma farmers depend solely on machines to harvest their cotton. Mechanical cotton harvesting requires less labor, reduces problems of securing workers, requires additional capital, and allows individual farmers to farm larger acreages; however, managers face unique problems.

Two important problems confronting the Oklahoma cotton farmer, who is considering mechanical harvesting are as follows:

1. Which type of machine should be used? That is, will stripping or picking his cotton allow him to minimize costs or attain other goals?
2. What plant preparation (if any) should be made prior to harvesting? That is, should the cotton be defoliated and/or desiccated before harvesting?

These problems will be discussed further under the headings of stripping vs. picking and plant preparation.

Stripping vs. Picking

Strippers remove all of the bolls and leaves from the stalk. Therefore, use of a stripper is feasible only after all of the bolls are mature. Waiting until all the bolls mature means that the farmer is taking a chance of having the open cotton damaged by hail, rain, or wind. Stripping often results in lower grades than picking.

Picking is an operation which harvests only the open cotton and allows the plant to continue to grow and develop the immature bolls. After more bolls have opened the picking operation may be repeated or the remainder of the crop may be stripped. Picking allows the farmer to harvest at least part of his crop early in the harvesting season. However, pickers are more expensive to purchase and maintain than strippers.

Effects of picking or stripping on net returns can be determined if the revenue and costs which change with the harvesting method are known or can be estimated.

Plant Preparation

The farm manager must decide if he should use plant preparation chemicals or allow cold weather to kill his cotton. Plant preparation chemicals make it possible to harvest the crop earlier by hastening the opening of mature bolls. Earlier harvesting frequently means better grades and higher prices, but if plant preparation materials are applied to plants with immature bolls, the quality and price will likely be reduced.

Plant preparation chemicals are of two types, defoliants and desiccants. Defoliants cause the plants to shed their leaves, but do not kill the plants. Therefore, a defoliant may be applied early in the harvesting season (after at least 60 percent of the bolls are open) and the open cotton can be harvested with a mechanical picker or by hand.

Desiccants kill the leaves and small stems and usually stop all growth activity. Desiccants are not recommended until all bolls are mature and at least 80 to 90 percent of the bolls are open. Waiting until 80 to 90 percent of the bolls are open means that the farmer is taking a chance of having the open cotton damaged by severe weather.

The appropriate plant preparation (if any) for various managerial goals can be determined if the revenue and costs which change with defoliation and/or desiccation are known or can be estimated.

Available Information

In the previous section, it was mentioned that estimates of costs and returns that change with plant preparation and the harvesting method are needed to determine the optimum harvesting strategy. Data for estimating these costs and returns are examined in this section.

Physical Data

The Agricultural Engineering Department, Oklahoma Agricultural Experiment Station, has conducted picker vs. stripper and plant preparation experiments.[1] The picker vs. stripper experiments were performed in irrigated cotton in the years 1957, 1959, 1960, and 1961. Special varieties have been developed for each of the harvesting methods, but some varieties possess desirable characteristics for both operations

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[1]The data used in this chapter were obtained from "Cotton Mechanization in Oklahoma," Oklahoma Agricultural Experiment Station Annual Reports, 1952-1961, and supplemental material to the annual reports.

(picking and stripping). Ordinarily, stripper varieties have storm resistance and a short staple. Acala 44 has a long staple and some storm resistance along with other stripper characteristics; therefore, it was chosen to be used in an experiment comparing picking and stripping irrigated cotton.

The plant preparation experiments consisted of three harvesting method-moisture culture combinations. That is, plant preparation experiments were performed for picker harvesting irrigated cotton in 1958 and 1959, stripper harvesting dryland cotton in 1958 and 1959, and stripper harvesting irrigated cotton in 1960.

A discussion of the forenamed experiments and the conditions prevalent in the various years is included in the empirical results section.

Economic Data

The prices of cotton lint used in this chapter were the government loan prices (for the grade and staple resulting from each treatment) in the year that the experiment was performed. Government loan prices were used because they are usually more stable than market prices.

The prices used in this chapter may involve a price level change between years. This price level change will not influence a comparison of the treatments within individual years, but a comparison across years will reflect the price level change. The effects of the price level change were not removed because (1) farmers must deal with price level changes as well as absolute prices, and treatments and prices may interact, and (2) a method for determining government loan price for cotton that has been classified on a grade index basis was not discovered. Prices used were recorded when the cotton was classified.

Input price assumptions are specified in the individual budgets in the empirical results section. Custom rates were used for the costs in the forthcoming budgets so that the results might be realistic for a wider range of conditions. That is, many farmers could not afford a picker and a stripper; however, they might hire one or both operations done.

Analytical Technique

Alternative harvesting strategies can be analyzed via a partial budgeting procedure. Net returns to factors held constant are defined as:

$$\text{Net Returns} = \text{Total Revenue} - \text{Total Variable Cost} \qquad (5.1)$$

Equation (5.1) can be modified as follows:

$$\text{Net Returns} = P_y \cdot Y - \sum_{i=1}^{n} P_{xi}\, X_i \qquad (5.2)$$

Equation (5.2) can be used to determine net returns for each alternative being considered. Game theory can be used to analyze the resulting net returns and to specify the compatibility of various goals and alternatives.

In the empirical results section of this chapter, budgets are used to summarize the results of alternative plant preparation and harvesting strategies. These budgets were derived by using equation (5.2). Only the variables which might be expected to change with different treatments are included in these budgets. Costs such as seedbed preparation, planting, and fertilizing would not be expected to change with a change in harvesting strategy; therefore, these costs are not included in the budgets. However, picking or stripping, ginning, bagging, and hauling would change and costs of each are included in the budgets.

Results of individual years as well as averages are useful in choosing harvesting strategies. In the absence of better estimates, an average (each alternative is considered to have an equal probability of occuring) may be satisfactory. However, when only a few observations are available, the estimate might be improved by multiplying results in individual years by estimates of probabilities of such years occurring.

Empirical Results

Picking vs. Stripping in 1957--Table XXI

The experiment in 1957 included three treatments, comparing picking vs. stripping of Acala 44. The experiment in 1957 met with severe weather difficulties throughout the season.

> Late spring rains delayed the planting date until the latter portion of June, cool autumn weather delayed opening of bolls, a hard freeze occurring two weeks earlier than normal froze all immature bolls and set leaves on the plants, then two weeks of rainy weather delayed harvest. As a result of the normal growing season being shortened at both ends by weather conditions, none of the bolls were open at the time of freezing. Of the two bales of bolls per acre estimated to be on the plants, approximately one third of them opened following the freeze and rain. The stalks and limbs were extremely rank and did not resemble stripper type plants as in the 1956 season. The tests were nonetheless executed in the intended manner in hopes that information of interest would be obtained.[2]

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[2]"Cotton Mechanization in Oklahoma," 1957, p. 80.

TABLE XXI

BUDGET OF PICKER VS. STRIPPER IN IRRIGATED COTTON, ALTUS, OKLAHOMA, 1957

		- Variety and Treatments -								
		Acala 44 Picked (about 11-15)			Acala 44 Picked (about 11-15) and Stripped (about 11-15)			Acala 44 Stripped (about 11-15)		
Item	Unit	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)
1. Production										
Harvested Material (hm)	lbs.		967			2051			3414	
Lint										
1st Harvest	cwt.[a]	24.26	3.24	78.60	24.26	3.24	78.60	11.00[b]	6.11	67.21
Grade			SLM Sp.[c]			SLM Sp.[c]			LMSP Bk.[d]	
Staple	1/32 in.		36			36			32	
2nd Harvest	cwt.[a]				9.00[b]	1.71	15.39			
Grade						BG Bk.[e]				
Staple	1/32 in.					36				
Gross Sales	acre			78.60			93.99			67.21
2. Costs[f]										
Defoliation	acre	3.25	1	3.25	3.25	1	3.25			
Ginning	cwt. (hm)	.70	9.67	6.77	.70	20.51	14.36	.70	34.14	23.90
Bagging	500 lbs. bale	5.00	.65	3.25	5.00	.99	4.95	5.00	1.22	6.10
Picking	lbs. lint	.06	324	19.44	.06	324	19.44			
Stripping (once over)	lbs. lint							.03	611	18.33
Stripping (scrapping)	lbs. (hm)				.01	1084	10.84			
Hauling	cwt. (hm)	.25	9.67	2.42	.25	20.51	5.13	.25	34.14	8.54
Total Specified Costs	acre			35.13			57.97			56.87
3. Returns Above Specified Costs	acre			43.47			36.02			10.34

[a] Includes proportionate weight of bagging and ties.

[b] Reduced because of bark.

[c] Strict Low Middling Spot.

[d] Low Middling Spot Bark.

[e] Below Grade Bark.

[f] Custom Rates.

Because of the extreme weather difficulties during the season the information in Table XXI is not considered typical. However, this type of year does happen and should be considered by the farm manager when choosing harvest strategies. It should be noted that the one picking treatment had lower gross sales but higher returns above specified costs than one picking followed by stripping. Thus, the added costs of ginning, bagging, stripping, and hauling the stripped cotton were greater than the added revenue because the grade and turnout of the cotton stripped following picking was low.

The once-over stripping operation resulted in very low returns above specified costs because the grade of the entire crop was very low and the expenses were high.

Picking vs. Stripping in 1959--Table XXII

The treatments included in the picker-stripper 1959 experiment are given in Table XXII. The growing season in 1959 was favorable and good yields resulted in all the treatments. Gross sales for all the treatments were within a $14 range. The reduction in grade due to bark on the stripped cotton following picking accounted for a large part of the variation in gross sales.

The returns above specified costs for both varieties which were stripped in a once-over operation were practically equal. Returns above specified costs were considerably lower for the treatments involving two harvests because of the added expense of defoliation and running the machines over the ground twice.

TABLE XXII

BUDGET OF PICKER VS. STRIPPER IN IRRIGATED COTTON, ALTUS, OKLAHOMA, 1959

		- Variety and Treatments -											
		Acala 44 Picked (11-2) and Picked (11-27)			Acala 44 Picked (11-2) and Stripped (11-27)			Acala 44 Stripped (11-27)			Western Stormproof Stripped (11-27)		
Item	Unit	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)
1. Production													
Harvested Material (hm)	lbs.		2166			2960			3116			2906	
Lint													
1st Harvest	cwt.[a]	36.37[b]	5.88	213.86	36.37[b]	5.88	213.86	31.83[b]	8.37	266.42	30.98[b]	8.62	267.05
Grade Index			100.0			100.0			95.2			96.7	
Staple	1/32 in.		35.1			35.1			33.1			30.9	
2nd Harvest	cwt.	36.28[b]	1.28	46.44	19.20[c]	2.09	40.13						
Grade Index			99.2			54.9[c]							
Staple	1/32 in.		35.9			33.1							
Gross Sales	acre			260.30			253.99			266.42			267.05
2. Costs[d]													
Defoliation	acre	3.25	1	3.25	3.25	1	3.25						
Ginning	cwt. (hm)	.70	21.66	15.16	.70	29.60	20.72	.70	31.16	21.81	.70	29.06	20.34
Bagging	500 lbs. bale	5.00	1.43	7.15	5.00	1.59	7.95	5.00	1.67	8.35	5.00	1.72	8.60
Picking	lbs. lint	.06	716	42.96	.06	588	35.28						
Stripping (once over)	lbs. lint							.03	837	25.11	.03	862	25.86
Stripping (scrapping)	lbs. (hm)				.01	1183	11.83						
Hauling	cwt. (hm)	.25	21.66	5.42	.25	29.60	7.40	.25	31.16	7.79	.25	29.06	7.26
Total Specified Costs	acre			73.94			86.43			63.06			62.06
3. Returns Above Specified Costs	acre			186.36			167.50			203.36			204.99

[a]Includes proportionate weight of bagging and ties.

[b]Based on 1959 CCC "A Plan" purchase prices.

[c]Reduced one grade because of bark. Lint value for this treatment estimated by cotton buyer.

[d]Custom rates.

Picking vs. Stripping in 1960--Table XXIII

The picker-stripper experiment in 1960 was beset with severe weather throughout the season.

> Acala 44 and Western Stormproof were the varieties chosen to represent the two types of cotton for this study. However, these varieties were destroyed by a hail storm in June. Two other varieties were then planted which were thought better suited to the short remaining growing season. These varieties were Austin for picker harvesting and Paymaster 101 for stripping. The cottons were grown under irrigation at the Irrigation Experiment Station at Altus. In mid-October, a severe hail storm defoliated the cotton, and also knocked considerable quantities of bolls from the plants. At this time, less than 50 percent of the Austin bolls were open, while the Paymaster cotton was approximately 75 percent open. Consequently, differences in lint yield between the two varieties at harvest time were much greater than would normally be expected.
>
> It was intended that one of the harvesting methods to be compared in this study would consist of a mid-season machine picking followed by a late season picking. But due to the late maturity of the Austin cotton and the fall hail storm, the double-picking method was omitted.[3]

The growing season for the picker-stripper experiment does not seem typical; however, the results do indicate the type of interaction one can experience with different weather, variety, and machine combinations. Such information is useful to the decision maker whether he puts little or great weight on one year's results. The grade of the scrapping stripped cotton was reduced because of bark. The once-over stripping of Austin resulted in a lower grade than the picked cotton or the stripped Paymaster cotton. Austin stripped once-over had a slightly shorter staple than picked Austin. Austin picked and stripped resulted in higher gross sales but lower returns above specified cost

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[3]"Cotton Mechanization in Oklahoma," 1960, p. 73.

TABLE XXIII

BUDGET OF PICKER VS. STRIPPER IN IRRIGATED COTTON, ALTUS, OKLAHOMA, 1960

		- Variety and Treatments -											
		Austin Picked (11-9)			Austin Picked (11-9) and Stripped (11-16			Austin Stripped (11-23)			Paymaster 101 Stripped (11-16)		
Item	Unit	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars	Quantity	Value or Cost (dollars)
1. Production													
Harvested Material (hm)	lbs.		582			1879			1600			2568	
Lint													
1st Harvest	cwt.[a]	30.04	2.06	61.88	30.04	2.06	61.88	23.29	2.57	59.86	27.74	6.71	186.14
Grade Index			94.0			94.0			81.7			94.7	
Staple	1/32 in.		32.5			32.5			31.0			30.3	
2nd Harvest	cwt.[a]				16.66[b]	1.50	24.99						
Grade Index						79.0							
Staple	1/32 in.					31.0							
Gross Sales	acre			61.88			86.87			59.86			186.14
2. Costs[c]													
Defoliation	acre	3.25	1	3.25	3.25	1	3.25						
Ginning	cwt. (hm)	.70	5.82	4.07	.70	18.79	13.15	.70	16.00	11.20	.70	25.68	17.98
Bagging	500 lbs. bale	5.00	.41	2.05	5.00	.71	3.55	5.00	.51	2.55	5.00	1.34	6.70
Picking	lbs. lint	.06	206	12.36	.06	206	12.36						
Stripping (once over)	lbs. lint							.03	257	7.71	.03	671	20.13
Stripping (scrapping)	lbs. (hm)				.01	1297	12.97						
Hauling	cwt. (hm)	.25	5.82	1.46	.25	18.79	4.70	.25	16.00	4.00	.25	25.68	6.42
Total Specified Costs	acre			23.19			49.98			25.46			51.23
3. Returns Above Specified Costs	acre			38.69			36.89			34.40			134.91

[a]Includes proportionate weight of bagging and ties.

[b]Reduced 7 cents per pound below CCC schedule because of bark.

[c]Custom rates.

than did Austin picked. That is, the revenue obtained from stripping after being picked was less than the costs incurred to obtain the additional revenue. This means that a manager under these circumstances would decrease net returns if he stripped the Austin cotton after it had been picked. In this particular year (1960) returns above specified costs were about $100 per acre higher for stripped Paymaster than for Austin harvested by any method. This seems to indicate that more chance taking is involved when a long staple cotton is raised. This seems reasonable because long staple cotton is usually also slow maturing.

Picking vs. Stripping in 1961--Table XXIV

The 1961 cotton season might be classified as normal or slightly more favorable than normal.

The grade from the once-over stripped cotton is slightly lower for both varieties. As would be expected, Western Stormproof had a slightly shorter staple than Acala 44. The staple of once-over stripped Acala 44 is slightly shorter than Acala 44 which was picked early, but longer than Acala 44 harvested late in the season.

The largest returns above specified costs were realized from the once-over stripped Acala 44. This was the result of the combined effects of high revenue and fairly low harvesting costs.

Picking vs. Stripping in a Normal Year--Table XXV

The normal budget (Table XXV) was computed in an effort to estimate what returns might be expected to be over time. The quantity and price components for Acala 44 of this normal budget are the average of the corresponding quantity and price components of each treatment for years

TABLE XXIV

BUDGET OF PICKER VS. STRIPPER IN IRRIGATED COTTON, ALTUS, OKLAHOMA, 1961

		- Variety and Treatments -											
		Acala 44 Picked (11-10) and Picked (12-27)			Acala 44 Picked (11-10) and Picked (12-27)			Acala 44 Stripped (12-27)			Western Stormproof Stripped (12-27)		
Item	Unit	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)
1. Production													
Harvested Material (hm)	lbs.		2221			3007			3403			2928	
1st Harvest	cwt.[a]	36.40	5.52	200.93	36.40	5.52	200.93	33.30	8.47	282.05	31.60	7.63	241.11
Grade Index			100.00			100.00			95.00			95.00	
Staple	1/32 in.		37.50			37.50			36.50			32.50	
2nd Harvest	cwt.[a]	35.60	2.03	72.27	31.80	2.29	72.82						
Grade Index			100.00			90.90							
Staple	1/32 in.		36.30			36.20							
Gross Sales	acre			273.20			273.75			282.05			241.11
2. Costs[b]													
Defoliation	acre	3.25	1	3.25	3.25	1	3.25						
Ginning	cwt. (hm)	.70	22.21	15.55	.70	30.07	21.05	.70	34.03	23.82	.70	29.28	20.50
Bagging	500 lbs. bale	5.00	1.51	7.55	5.00	1.56	7.80	5.00	1.69	8.45	5.00	1.53	7.65
Picking	lbs. lint	.06	755	45.30	.06	552	33.12						
Stripping (once over)	lbs. lint							.03	847	25.41	.03	763	22.89
Stripping (scrapping)	lbs. (hm)				.01	1391	13.91						
Hauling	cwt. (hm)	.25	22.21	5.55	.25	30.07	7.52	.25	34.03	8.51	.25	29.28	7.32
Total Specified Costs	acre			77.20			86.65			66.19			58.36
3. Returns Above Specified Costs	acre			196.00			187.10			215.86			182.75

[a]Includes proportionate weight of bagging and ties.

[b]Custom rates.

TABLE XXV

NORMAL BUDGET OF PICKER VS. STRIPPER IN IRRIGATED COTTON, ALTUS, OKLAHOMA

		- Variety and Treatments -											
		Acala 44 Picked and Picked			Acala 44 Picked and Stripped			Acala 44 Stripped			Western Stormproof Stripped		
Item	Unit	Price Per Unit	Quantity	Value or Cost	Price Per Unit	Quantity	Value or Cost	Price Per Unit	Quantity	Value or Cost	Price Per Unit	Quantity	Value or Cost
		(dollars)		(dollars)	(dollars)		(dollars)	(dollars)		(dollars)	(dollars)		(dollars)
1. Production													
Harvested Material (hm)	lbs.		1785			2673			3311			2964	
Lint													
1st Harvest	cwt.[a]	32.34	4.88	157.82	32.34	4.88	157.82	25.38	7.65	194.16	24.39	7.38	180.00
Staple	1/32 in.		36.20			36.20			33.87			30.85	
2nd Harvest	cwt.[a]	23.96	1.10	26.36	20.00	2.03	40.60						
Staple	1/32 in.		36.00			34.55							
Gross Sales	acre			184.18			198.42			194.16			180.00
2. Costs[b]													
Defoliation	acre	3.25	1	3.25	3.25	1	3.25						
Ginning	cwt. (hm)	.70	17.85	12.50	.70	26.73	18.71	.70	33.11	23.18	.70	29.64	20.75
Bagging	500 lbs. bale	5.00	1.20	6.00	5.00	1.38	6.90	5.00	1.53	7.65	5.00	1.48	7.40
Picking	lbs. lint	.06	598	35.88	.06	488	29.28						
Stripping (once over)	lbs. lint							.03	765	22.95	.03	738	22.14
Stripping (scrapping)	lbs. (hm)				.01	1219	12.19						
Hauling	cwt. (hm)	.25	17.85	4.46	.25	26.73	6.68	.25	33.11	8.28	.25	29.64	7.41
Total Specified Costs	acre			62.09			77.01			62.06			57.70
3. Returns Above Specified Costs	acre			122.09			121.41			132.10			122.30

[a] Includes proportionate weight of bagging and ties.

[b] Custom rates.

1957, 1959, and 1961. For example, in Table XXV, the price for first harvest of Acala picked twice (32.34) was obtained by computing the average of the price received for first harvest in 1957 (24.26), the price received for first harvest in 1959 (36.37), and the price received for first harvest in 1961 (36.40). Likewise, the pounds of harvested material, pounds of lint, staple length, and price for second harvest were each computed in a similar manner. The above computations amount to assigning each of the years 1957, 1959, and 1961 a probability of one-third. The treatments in 1960 were not used in computing the normal budget because of variety differences.

The price and quantity components of the Western Stormproof treatment were computed such that the average yield ratio for the years 1959 and 1961 between Acala 44 stripped and Western Stormproof stripped was maintained.

According to the normal budget, Acala 44 once-over can be expected (on the average) to result in returns above specified costs about $10 greater than the other harvest strategies.

The net returns resulting from various picker-stripper treatments in different years can be summarized in a matrix such as the following:

Strategy Number	Harvest Strategies	States of Nature (Years)				
		1957	1959	1960[4]	1961	Normal
	Type of Year[5]	-	+	-	+	0
1.	Plant a picker (long staple) cotton and pick the entire crop	43.47	186.36	38.69	196.00	122.09
2.	Plant a picker (long staple) cotton and pick once, strip once	36.02	167.56	36.89	187.10	121.41
3.	Plant a picker (long staple) cotton and strip entire crop	10.34	203.36	34.40	215.86	132.10
4.	Plant a stripper cotton and strip entire crop	---	204.99	134.91	182.75	122.30

More years of data are needed before definite conclusions can be made regarding the optimum harvesting strategy. However, some remarks will be made based on the information at hand.

In normal years (or over the long run) the returns for all of the treatments are within a $11 range, but stripping the entire crop of a long staple cotton (strategy 3) results in returns above specified costs being approximately $10 higher than for the other treatments. If a manager wishes to maximize returns over time[6] and does not care what his returns in any particular time period are, he would choose strategy number three.

However, following strategy number 3 involves severe income fluctuations because long staple cotton is usually slow maturing and lacks storm resistance.

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[4]Different varieties were used in 1960 than in the other three years; therefore, 1960 was not considered in computing net returns for the normal column.

[5]Normal, favorable, and unfavorable years are represented by zero, plus, and minus, respectively.

[6]See Chapter I, pp. 8-11, for a discussion of managerial goals.

In unfavorable years (1960) stripping a short staple cotton was best and the relationship is consistant with expectations because stripper varieties are usually storm resistant and fast maturing. A manager should choose this strategy if he wishes to maximize security level.

In favorable years, all of the treatments give fairly high net returns, but any one treatment is not consistently better than the other strategies.

The preceding budgets and discussion have assumed a particular plant preparation and price for the various harvest strategies. However, plant preparation and prices may vary and will be discussed later in this chapter.

Plant Preparation for Picking Irrigated Cotton in 1958--Table XXVI

Defoliation of irrigated Acala 44 cotton in 1958 resulted in $31.78 per acre larger returns above specified costs than similar cotton which had not been defoliated. This additional returns above specified costs resulted from increased gross sales. Gross sales were larger for the defoliated plot because of the increased harvested yield and improved grade. Improvement in grade due to defoliation is easily accounted for by the lack of leaf trash in the lint, and the increase in the harvested yield seems reasonable because the leaves and stems are not in the picker's way. Defoliation seems to increase the size of the first harvest which means that the likelihood of the cotton being damaged by weather is smaller.

TABLE XXVI

BUDGET OF PLANT PREPARATION FOR PICKING IRRIGATED ACALA 44 COTTON, ALTUS, OKLAHOMA, 1958

		- Harvest Date and Treatments -					
		Defoliated (10-14) Picked (10-28) Picked (11-11)			Not Defoliated Picked (10-28) Picked (11-11)		
Item	Unit	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)
1. Production							
Harvested Material (hm)	lbs.		2567			2515	
Lint							
1st Picking	cwt.	36.38	7.96	289.58	33.74	7.28	245.63
Grade Index			99.56			97.00	
Staple	1/32 in.		33.61			33.61	
2nd Picking	cwt.	32.89	1.06	34.86	32.89	1.24	40.78
Grade Index			97.72			97.72	
Staple	1/32 in.		32.88			32.88	
Gross Sales	acre			324.44			286.41
2. Costs[a]	acre						
Defoliation	acre	3.25	1	3.25			
Bagging	500 lbs. bale	5.00	1.80	9.00	5.00	1.70	8.50
Ginning	cwt. hm	.70	25.67	17.97	.70	25.15	17.60
Picking	lbs. lint	.06	902	54.12	.06	852	51.12
Hauling	cwt. hm	.25	25.67	6.42	.25	25.15	6.29
Total Specified Costs	acre			90.76			83.51
3. Returns Above Specified Costs	acre			233.68			202.90

[a]Custom rates.

Plant Preparation for Picking Irrigated Cotton in 1959--Table XXVII

In 1959, returns above specified costs were $18.62 per acre higher for the defoliated treatment than for the nondefoliated cotton. The grade and staple was the same for the defoliated and nondefoliated cotton; however, the total harvested yield for the defoliated was eighty-four pounds per acre greater than the nondefoliated cotton. This increase in harvested yield accounted for the increase in returns above specified cost.

Plant Preparation for Picking Irrigated Cotton in a Normal Year--Table XXVIII

The various price and quantity components of the normal budget presented in Table XXVIII were computed by averaging the corresponding price and quantity components in Tables XXVI and XXVII. According to the normal budget, returns above specified costs for defoliated, irrigated, picked cotton average $23.81 per acre more than similar cotton which is not defoliated. Total specified costs are greater for the defoliated cotton, but gross sales are increased more than costs. The large increase in gross sales results from increased harvested yield. On the average, 66 pounds per acre more lint was harvested from the defoliated cotton than from the nondefoliated cotton.

Based on the data at hand, defoliating irrigated cotton before harvesting should be practiced if the manager has a goal of maximizing returns above specified costs or maximizing security level.

Plant Preparation for Stripper Harvesting Dryland Cotton in 1958--Table XXIX

The 1958 returns above specified costs were the highest for the no-plant treatment plot. This was largely the result of high gross sales; however, total specified costs were also small. The defoliated

TABLE XXVII

BUDGET OF PLANT PREPARATION FOR PICKING IRRIGATED ACALA 44 COTTON, ALTUS, OKLAHOMA, 1959

Item	Unit	- Harvest Date and Treatments - Defoliated (10-29) Picked (11-12) Picked (12-1)			Not Defoliated Picked (11-12) Picked (12-1)		
		Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)
1. Production							
Harvested Material (hm)	lbs.		2087			1921	
Lint							
1st Picking	cwt.	34.79	6.73	234.14	34.79	5.75	200.04
Grade Index			100			100	
Staple	1/32 in.		32.89			32.89	
2nd Picking	cwt.	34.00	.75	25.50	34.00	.89	30.26
Grade Index			100			100	
Staple	1/32 in.		32.89				
Gross Sales	acre			259.64			230.30
2. Costs[a]							
Defoliation	acre	3.25	1	3.25			
Bagging	500 lbs. bale	5.00	1.50	7.50	5.00	1.33	6.65
Ginning	cwt. hm	.70	20.87	14.61	.70	19.21	13.45
Picking	lbs. lint	.06	748	44.88	.06	664	39.84
Hauling	cwt. hm	.25	20.87	5.22	.25	19.21	4.80
Total Specified Costs	acre			75.46			64.74
3. Returns Above Specified Costs	acre			184.18			165.56

[a]Custom rates.

TABLE XXVIII

NORMAL BUDGET OF PLANT PREPARATION FOR PICKING IRRIGATED ACALA 44 COTTON, ALTUS, OKLAHOMA

Item	Unit	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)
1. Production							
Harvested Material (hm)	lbs.		2327			2218	
Lint							
1st Picking	cwt.	35.58	7.34	261.16	34.26	6.52	223.38
Staple	1/32 in.		33.25			33.25	
2nd Picking	cwt.	33.44	.90	30.10	33.44	1.06	35.45
Staple	1/32 in.		32.88			32.88	
Gross Sales	acre			291.26			258.83
2. Costs[a]							
Defoliation	acre	3.25	1	3.25			
Bagging	500 lbs. bale	5.00	1.65	8.25	5.00	1.52	7.60
Ginning	cwt. hm	.70	23.27	16.29	.70	22.18	15.53
Picking	lbs. lint	.06	824	49.44	.06	758	45.48
Hauling	cwt. hm	.25	23.27	5.82	.25	23.27	5.82
Total Specified Costs	acre			83.05			74.43
3. Returns Above Specified Costs	acre			208.21			184.40

[a] Custom rates.

TABLE XXIX

BUDGET OF PLANT PREPARATION FOR STRIPPER HARVESTING DRYLAND PARROTT COTTON, CHICKASHA, OKLAHOMA, 1958

		- Treatment and Date -														
		Defoliated (9-13)[a] Harvested (10-1)			Desiccated (9-20)[b] Harvested (10-1)			Defoliated (9-13)[c] Desiccated (9-20) Harvested (10-1)			Defoliated (10-16)[d] Frost (10-28) Harvested (11-6)			No Plant Treatment[e] Frost (10-28) Harvested (11-6)		
Item	Unit	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)
1. Production																
Harvested Material (hm)	lbs.		1256			1167			1128			1115			1262	
Green Bolls	lbs.	.01[f]	106	1.06	.01[f]	.95	95	.01[f]	73	.73	.01[f]	16	.16	.01[f]	17	.17
Ginned Material (gm)[g]	lbs.		1150			1072			1055			1099			1245	
Grade Index			91.39			89.44			89.94			88.11			89.78	
Staple	1/32 in.		29.22			29.66			29.33			28.94			29.72	
Lint	cwt.	24.84	2.97	73.77	24.90	2.87	71.46	24.18	2.78	67.22	23.22	2.98	69.20	25.11	3.31	83.11
Gin Turnout[h]	percent		25.8			26.8			26.4			27.1			26.6	
Gross Sales	acre			74.83			72.41			67.95			69.36			83.28
2. Costs[i]																
Defoliation	acre	3.25	1	3.25				3.25	1	3.25	3.25	1	3.25			
Desiccation	acre				2.90	1	2.90	2.90	1	2.90						
Bagging	500 lbs. bale	5.00	.59	2.95	5.00	.57	2.85	5.00	.56	2.80	5.00	.60	3.00	5.00	.66	3.30
Ginning	cwt. (hm)	.70	11.50	8.05	.70	10.72	7.50	.70	10.55	7.38	.70	10.99	7.69	.70	12.45	8.72
Stripping	lbs. lint	.03	297	8.91	.03	287	8.61	.03	278	8.34	.03	298	8.94	.03	331	9.93
Hauling	cwt. (hm)	.25	12.56	3.14	.25	11.67	2.92	.25	11.28	2.82	.25	11.15	2.79	.25	12.62	3.16
Total Specified Costs	acre			26.30			24.78			27.49			25.67			25.11
3. Returns Above Specified Costs	acre			48.53			47.63			40.46			43.69			58.17

[a]Defoliate the cotton when approximately 60 percent open and harvest two to three weeks later, but before frost.

[b]Desiccate one week after 60 percent open and harvest one to two weeks after desiccation, but before frost.

[c]Defoliate when 60 percent open, one week later desiccate, harvest one to two weeks after desiccation, but before frost.

[d]Defoliate approximately two weeks before normal frost date and harvest after frost.

[e]No plant treatment and harvest after frost.

[f]Estimated value of green bolls.

[g]Ginned material = Harvested material - Green bolls.

[h]Gin turnout = $\frac{\text{lbs. lint}}{\text{ginned material}}$.

[i]Custom rates.

plot had the second highest returns above specified costs which were approximately $10.00 per acre less than the no-plant treatment plot. The grade index only varied about three percent for all of the treatments. The treatments which were harvested after frost resulted in fewer green bolls and larger yields of lint; however, apparently the defoliated and harvest after frost decreased yield slightly. This probably resulted from the spray rig going through the field and damaging the cotton.

Plant Preparation for Stripper Harvesting Dryland Cotton in 1959--Table XXX

The no-plant treatment in 1959 gave the highest returns above specified costs primarily because the total specified costs were the smallest of any of the treatments. The defoliated and desiccated plot had the highest gross sales and highest total specified costs. However, it had the second highest returns above specified costs which were $4.00 per acre lower than the no-plant treatment plot. None of the treatments had very many green bolls at the time of harvest. The after frost harvests had slightly shorter staple. The other three treatments resulted in returns above specified costs of approximately $10.00 or $11.00 per acre lower than the no-plant-treatment plot.

Plant Preparation for Stripper Dryland Cotton in a Normal Year--Table XXXI

The various price and quantity components of the normal budget presented in Table XXXI were computed by averaging the corresponding price and quantity components in Tables XXIX and XXX. According to the normal budget, the no-plant treatment plot has the highest gross sales and yield, but the lowest total specified cost. Returns above specified costs are greatest for the no-plant treatment. The other four

TABLE XXX

BUDGET OF PLANT PREPARATION FOR STRIPPER HARVESTING DRYLAND PARROTT COTTON, CHIKCASHA, OKLAHOMA, 1959

		- Treatment and Date -														
		Defoliated (10-14)[a] Harvested (10-29)			Desiccated (10-22)[b] Harvested (10-29)			Defoliated (10-14)[c] Desiccated (10-22) Harvested (10-29)			Defoliated (10-21)[d] Frost (11-6) Harvested (11-21)			No Plant Treatment[e] Frost (11-6) Harvested (11-21)		
Item	Unit	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)
1. Production																
Harvested Material (hm)	lbs.		830			842			937			864			908	
Green Bolls	lbs.	.01[f]	41	.41	.01[f]	40	.40	.01[f]	38	.38	.01[f]	24	.24	.01[f]	21	.21
Ginned Material (gm)[g]	lbs.		789			798			899			840			887	
Grade Index			92.0			92.0			94.1			90.9			94.6	
Staple	1/32 in.		29.3			29.2			29.7			28.7			28.8	
Lint	cwt.	27.35	2.17	59.35	27.50	2.15	59.12	28.67	2.52	72.25	26.32	2.36	62.12	27.65	2.54	70.23
Gin Turnout[h]	percent		27.5			26.9			28.0			28.1			28.6	
Gross Sales	acre			59.76			59.52			72.63			62.36			70.44
2. Costs[i]																
Defoliation	acre	3.25	1	3.25				3.25	1	3.25	3.25	1	3.25			
Desiccation	acre				2.90	1	2.90	2.90	1	2.90						
Bagging	500 lbs. bale	5.00	.43	2.15	5.00	.43	2.15	5.00	.50	2.50	5.00	.47	2.35	5.00	.51	2.55
Ginning	cwt. (gm)	.70	7.89	5.52	.70	7.98	5.59	.70	8.99	6.29	.70	8.40	5.88	.70	8.87	6.21
Stripping	lbs. lint	.03	217	6.51	.03	215	6.45	.03	252	7.56	.03	236	7.08	.03	254	7.62
Hauling	cwt. (hm)	.25	8.30	2.08	.25	8.42	2.10	.25	9.37	2.34	.25	8.64	2.16	.25	9.08	2.27
Total Specified Costs	acre			19.51			19.19			24.84			20.72			18.65
3. Returns Above Specified Costs	acre			40.25			40.33			47.79			41.64			51.79

[a] Defoliate when approximately 60 percent open and harvest approximately two weeks later, but before frost.

[b] Desiccate one week after 60 percent open and harvest one week after desiccation, but before frost.

[c] Defoliate when 60 percent open, one week later desiccate, harvest one week after desiccation, but before frost.

[d] Defoliate approximately two weeks before normal frost date and harvest after frost.

[e] No plant treatment and harvest after frost.

[f] Estimated value of green bolls.

[g] Ginned material = Harvested material - Green bolls.

[h] Gin turnout $= \frac{\text{lbs. lint}}{\text{ginned material}}$.

[i] Custom rates.

TABLE XXXI

NORMAL BUDGET OF PLANT PREPARATION FOR STRIPPER HARVESTING DRYLAND PARROTT COTTON, CHICKASHA, OKLAHOMA

		- Treatments -														
		Defoliated[a] HBF			Desiccated[b] HBF			Defoliated[c] Desiccated HBF			Defoliated[d] HAF			No Plant Treatment[e] HAF		
Item	Unit	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)	Price Per Unit (dollars)	Quantity	Value or Cost (dollars)
1. Production																
Harvested Material (hm)	lbs.		1043			1004			1032			990			1085	
Green Bolls	lbs.	.01[f]	74	.74	.01[f]	68	0.68	.01[f]	56	.56	.01[f]	20	.20	.01[f]	19	.19
Ginned Material (gm)[g]	lbs.		969			936			976			970			1066	
Staple	1/32 in.		29.26			29.43			29.52			28.82			29.26	
Lint	cwt.	26.10	2.57	67.08	26.20	2.51	65.76	26.42	2.65	70.01	24.77	2.67	66.14	26.38	2.92	77.03
Gin Turnout[h]	percent		26.5			26.8			27.2			27.5			27.4	
Gross Sales	acre			67.82			66.44			70.57			66.34			77.22
2. Costs[i]																
Defoliation	acre	3.25	1	3.25				3.25	1	3.25	3.25	1	3.25			
Desiccation	acre				2.90	1	2.90	2.90	1	2.90						
Bagging	500 lbs. bale	5.00	.51	2.55	5.00	.50	2.50	5.00	.53	2.65	5.00	.53	2.65	5.00	.58	2.90
Ginning	cwt. (gm)	.70	9.69	6.78	.70	9.36	6.55	.70	9.76	6.83	.70	9.70	6.79	.70	10.66	7.46
Stripping	lbs. lint	.03	257	7.71	.03	251	7.53	.03	265	7.95	.03	267	8.01	.03	292	8.76
Hauling	cwt. (hm)	.25	10.43	2.61	.25	10.04	2.51	.25	10.32	2.58	.25	9.90	2.48	.25	10.85	2.71
Total Specified Costs	acre			22.90			21.99			26.16			23.18			21.83
3. Returns Above Costs	acre			44.92			44.45			44.41			43.16			55.39

[a]Defoliate when approximately 60 percent open and harvest approximately two weeks later, but before frost.

[b]Desiccate one week after 60 percent open and harvest one to two weeks after desiccation, but before frost.

[c]Defoliate when 60 percent open, one week later desiccate, harvest one week after desiccation, but before frost.

[d]Defoliate approximately two weeks before normal frost date and harvest after frost.

[e]No plant treatment and harvest after frost.

[f]Estimated value of green bolls.

[g]Ginned material = Harvested material - Green bolls.

[h]Gin turnout = $\frac{\text{lbs. lint}}{\text{ginned material}}$

[i]Custom rates.

treatments return from $10.47 to $12.23 per acre smaller returns above specified cost. The treatments which were harvested after frost yielded the highest gin turnout. The combined effects of high yield and the lack of plant preparation costs result in the highest returns above specified costs for the no-plant treatment plot. However, no plant preparation will require that the cotton be left in the field longer; therefore, more chance-taking will be involved.

Plant Preparation for Stripper Harvesting Irrigated Cotton in 1960--Table XXXII

Returns above specified costs are the highest and approximately equal for the defoliated and the no-plant-treatment plots. Gross sales and total specified costs are approximately equal for both of these treatments. The additional revenue from green bolls on the defoliated plot approximately offset the additional yields from the no-treatment plot.

Returns above specified costs are approximately $25.00 per acre lower for defoliated and desiccated cotton than for either defoliated or no-plant treatment. This results largely from loss in gross sales. It is thought that the loss in gross sales was caused by (1) the spray rig going through the field twice and damaging the cotton, (2) the desiccant stopping the growth and development of the green bolls.

The returns above specified costs for the desiccated plot are $65.00 per acre lower than for the no-treatment plot. This difference resulted from loss in gross sales which was caused largely by desiccation decreasing the yield by stopping growth and development of green bolls.

Only one year's data are available on plant preparation for stripper harvesting irrigated cotton; however, in 1960, returns above specified

TABLE XXXII

BUDGET OF PLANT PREPARATION FOR STRIPPER HARVESTING IRRIGATED ACALA 44 COTTON, CHICKASHA, OKLAHOMA, 1960

		- Treatment and Date -											
		Defoliated (10-5)[a] Harvested (11-3)			Desiccated (10-15)[b] Harvested (11-3)			Defoliated (10- 5)[c] Desiccated (10-15) Harvested (11-3)			No Plant Treatment[d] Harvested (11-26)		
Item	Unit	Price Per Unit	Quantity	Value or Cost	Price Per Unit	Quantity	Value or Cost	Price Per Unit	Quantity	Value or Cost	Price Per Unit	Quantity	Value or Cost
		(dollars)		(dollars)	(dollars)		(dollars)	(dollars)		(dollars)	(dollars)		(dollars)
1. Production													
Harvested Material (hm)	lbs.		3560			3756			3044			3364	
Green Bolls	lbs.	.01[e]	741	7.41	.01[e]	968	9.68	.01[e]	384	3.84	.01[e]	194	1.94
Ginned Material (gm)[f]	lbs.		2819			2788			2660			3170	
Grade Index			96.0			88.6			92.3			88.6	
Staple	1/32 in.		34.3			34.4			33.3			34.1	
Lint	cwt.	32.15	6.65	213.80	28.98	4.77	138.23	29.68	6.47	192.03	30.32	7.27	220.43
Gin turnout[g]	percent		23.6			17.1			24.3			22.9	
Gross Sales	acre			221.21			147.91			195.87			222.37
2. Costs[h]													
Defoliation	acre	3.25	1	3.25				3.25	1	3.25			
Desiccation					2.90	1	2.90	2.90	1	2.90			
Bagging	500 lbs. bale	5.00	1.33	6.65	5.00	.95	4.75	5.00	1.29	6.45	5.00	1.45	7.25
Ginning	cwt. (gm)	.70	28.19	19.73	.70	27.88	19.52	.70	26.60	18.62	.70	31.70	22.19
Stripping	lbs. lint	.03	665	19.95	.03	477	14.31	.03	647	19.41	.03	727	21.81
Hauling	cwt. (hm)	.25	35.60	8.90	.25	37.56	9.39	.25	30.44	7.61	.25	33.64	8.41
Total Specified Costs	acre			58.48			50.87			58.24			59.66
3. Returns Above Specified Costs	acre			162.73			97.04			137.63			162.71

[a] Defoliate, harvest before frost.

[b] Desiccate, harvest before frost.

[c] Defoliate, desiccate, and harvest before frost.

[d] No plant treatment, harvest after frost.

[e] Estimated value of green bolls.

[f] Ginned material = Harvested material - Green bolls.

[g] Gin turnout = $\frac{\text{lbs. lint}}{\text{ginned material}}$.

[h] Custom rates.

costs apparently were not changed by defoliation. Defoliation might be justified because it allows earlier harvesting and less chance-taking.

Seasonal Price Variation

The prices used thus far in this chapter have been the government loan prices for the respective years. These prices were used because they are more stable than market prices. However, plant preparation and method of harvesting may influence the price received for cotton in three ways:

(1) Time of harvest--The price level may change any time, but if cotton prices are characterized by seasonal variations during the harvesting season, it would be profitable to harvest and sell the cotton when the price is the highest, other things being equal.

(2) The grade of cotton is often changed by weather.

(3) Too early application of plant preparation chemicals may shorten staple.

Since a combination of these factors is most likely, a measurement of the combined effects of them was sought. A Seasonal Index of Oklahoma Cotton Lint Farm Prices should reflect the combined effects of the above factors; therefore, a simple seasonal index was computed for the years 1954-61 and is given in Table XXXIII and shown in Figure 1. This seasonal index was computed by dividing each monthly average index by the overall average index.

From Figure 1, it can be seen that the Seasonal Index of Oklahoma Cotton Lint Farm Price has a fairly steep negative slope after the middle of September. This indicates that a higher price is usually received for

TABLE XXXIII

COTTON LINT: INDEX OF OKLAHOMA FARM PRICE

Year	Aug.	Sept.	Oct.	Nov.	Dec.
	- Average 1910-14 = 100 -				
1961	261	283	283	275	269
1960	261	275	261	246	236
1959	269	274	265	247	236
1958	283	284	275	269	237
1957	252	261	254	241	186
1956	268	247	252	242	234
1955	274	281	258	256	239
1954	278	280	277	269	266
Total	2146	2185	2125	2045	1903
No. of years	8	8	8	8	8
Monthly Average	268.25	273.125	265.625	255.625	237.875
Overall Average	260.100				
Seasonal Index	103.13	105.01	102.12	98.28	91.46

Source: Monthly indices were obtained from "Prices Received by Oklahoma Farmers 1910-1957," p. 85; "1959 Supplement to Prices Received by Oklahoma Farmers 1910-1957," p. 15; and "1962 Supplement to Prices Received by Oklahoma Farmers 1910-1957," p. 15.

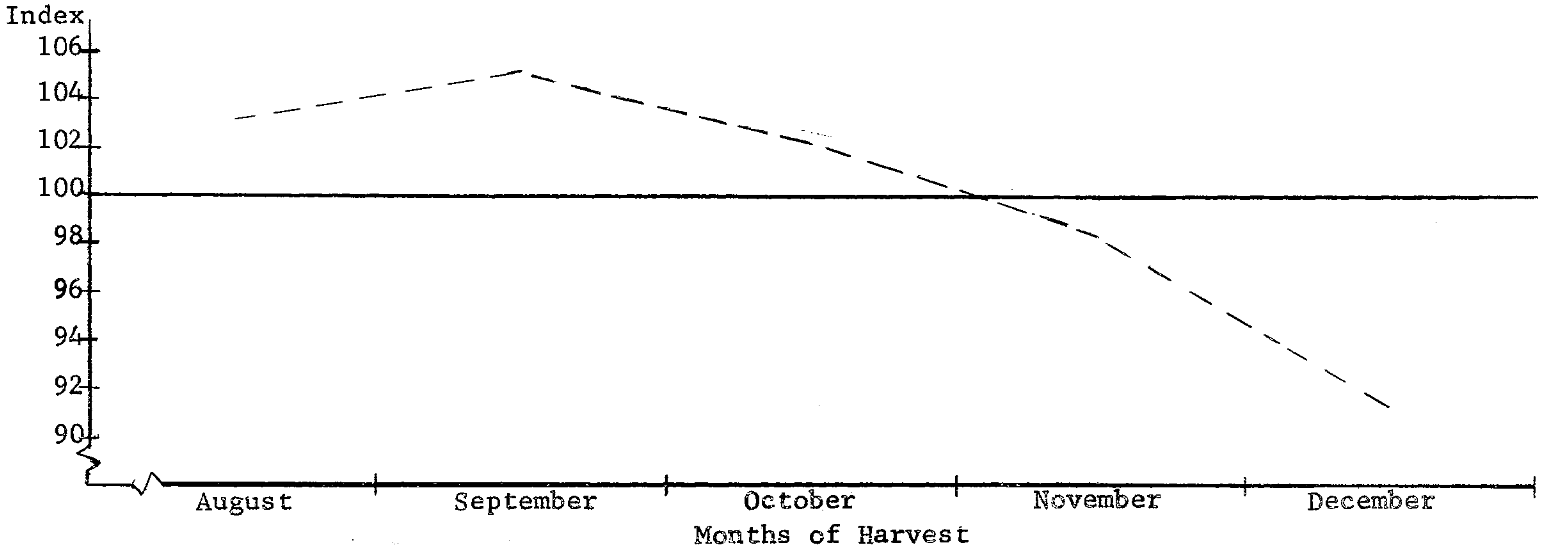

Figure 1. Seasonal Index of Oklahoma Cotton Lint Farm Price

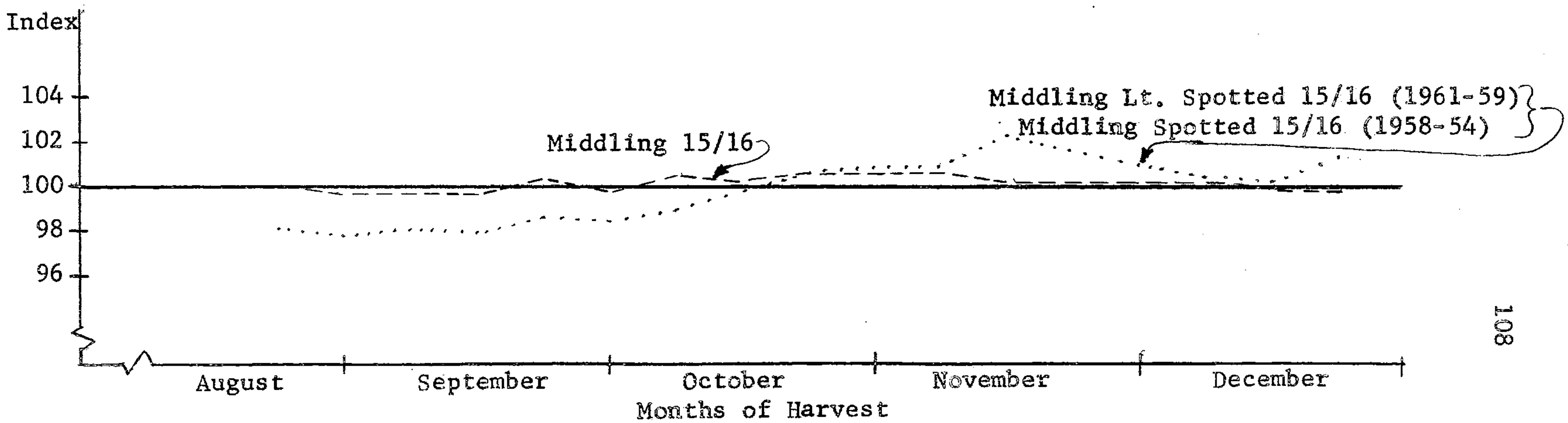

Figure 2. Seasonal Price Indices for Middling 15/16, Middling Lt. Spotted 15/16, and Middling Spotted 15/16 Cotton on the Lubbock Market

cotton sold early in the season. The farm manager might want to consider the seasonal price variation when choosing production and harvesting strategies.

Seasonal indices for six grade and staple combinations were computed in an attempt to determine the individual influence of grade, staple, and time of harvest. These grades and staples are six of the most common combinations of Oklahoma cotton and are listed in Appendix Tables VI through XI, and graphed in Figures 2, 3, and 4.

In the 1960-61 crop season, 70 percent of Oklahoma cotton received a grade of light spot.[7] The light spot designation has only been used since 1959. Thus, it was necessary to choose the grade which corresponded as near as possible to light spotted in previous years. For this reason, Middling Spotted 15/16 was used for 1954 through 1958.

It can be seen from Figures 2, 3, and 4 that the prices vary slightly for the various combinations of grades and staples, but no significant price trends for the harvesting season are evident. Thus, the trend towards lower prices as the harvesting season progresses is the result of lower grades and/or shorter staples rather than changes in the price level.

The budgets of this chapter took into account changes in grade and staple. Thus, using government loan prices did not damage the validity of the budgets.

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[7]"Oklahoma: Cotton Quality Report For Ginnings For 1961--62 Season" United States Department of Agriculture, Agricultural Marketing Service, Cotton Division, March 20, 1962.

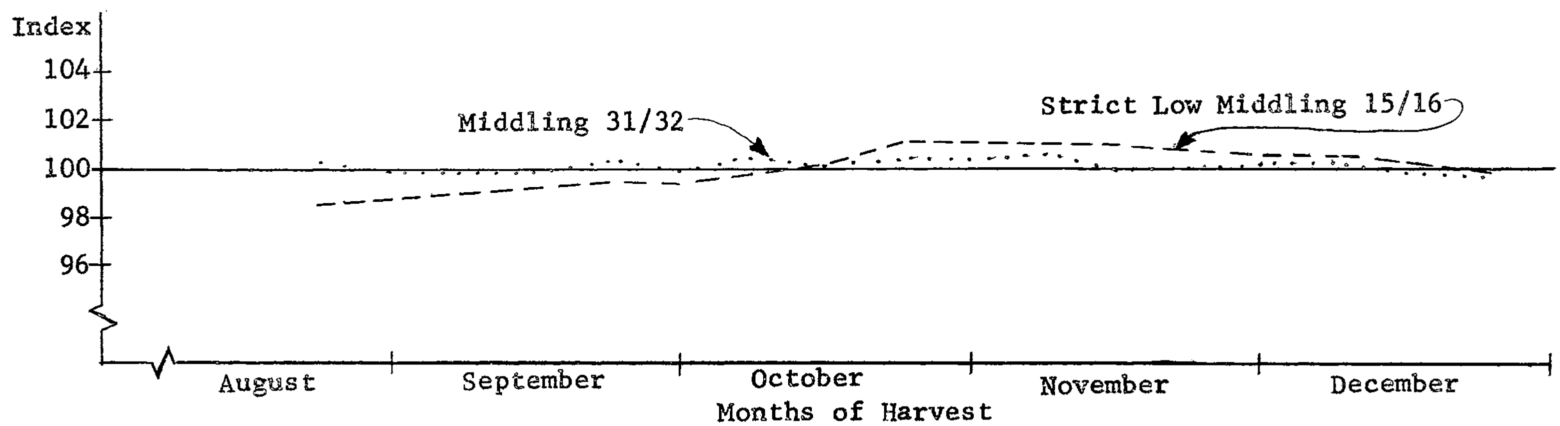

Figure 3. Seasonal Price Indices for Middling 31/32 and Strict Low Middling 15/16 Cotton On the Lubbock Market

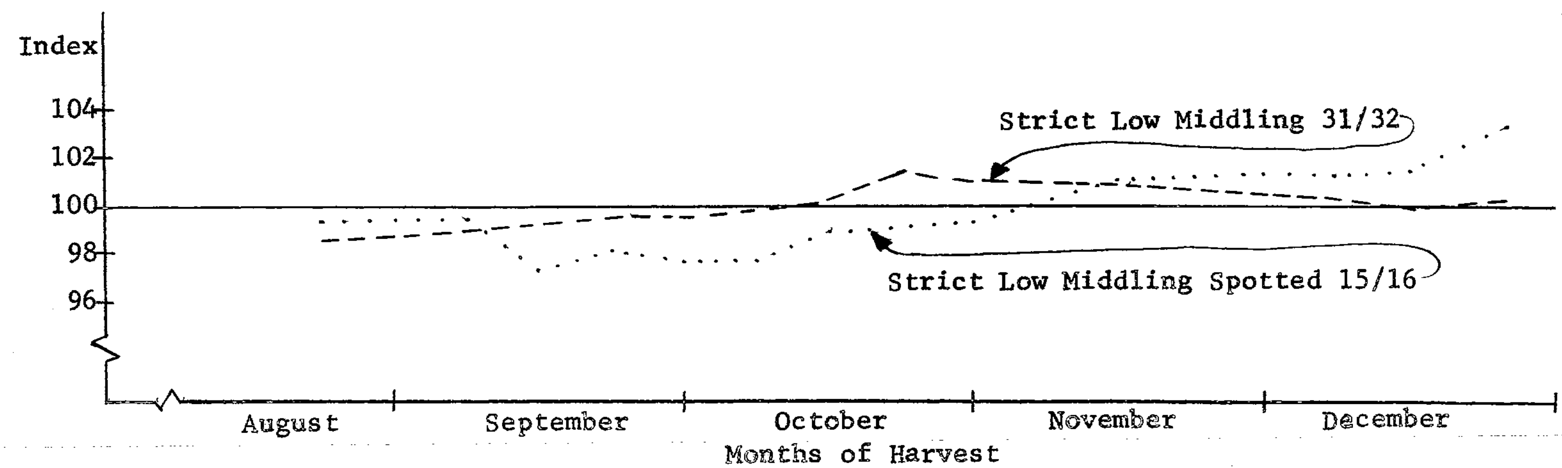

Figure 4. Seasonal Price Indices for Strict Low Middling 31/32 and Strict Low Middling Spotted 15/16 Cotton on the Lubbock Market

Summary

The analysis in this chapter indicates that the "best" harvest strategy depends on the manager's goals. More experimentation is needed before definite conclusions can be reached regarding the optimum harvest and plant preparation strategy. A brief summary is given below; however, it should be considered only in the light of the conditions mentioned, prices used, and assumptions made throughout this chapter.

Planting a long staple cotton on irrigated land and stripping the entire crop seems to be the strategy which allows the manager to maximize returns above specified costs. However, planting a stripper type cotton on irrigated land and stripping the entire crop allows the farmer to maximize security level.

In 1958 and 1959, defoliation in preparation for picking irrigated cotton resulted in higher returns above specified costs than the cotton not defoliated prior to picking. This indicates that in those years, defoliation would have been a farmer's optimum production strategy if he had a managerial goal of maximum net returns or security level.

For stripper harvesting of dryland cotton, the plot with no-plant-treatment had the highest returns above specified costs in 1958 and 1959. This indicates that in those years, the farmer's optimum production strategy would have been to allow cold weather to prepare his plants for stripping.

In 1960, returns above specified costs were highest and approximately equal for the defoliated and the no-plant treatment plots in the plant preparation for stripper harvesting irrigated cotton experiment. In this one year, returns above specified costs apparently were not changed by defoliation; however, defoliation might be justified because it allows earlier harvesting and less chance-taking.

The decrease in the price of cotton as the harvesting season progresses is the result of lower grades and/or shorter staples, rather than pure price seasonality.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The objectives of this study were (1) to increase the usefulness of technological research information, (2) to present tools whereby farmers and researchers may evaluate forthcoming technological developments, and (3) to make suggestions regarding design, method, or reporting of research which might increase its usefulness to farmers or other researchers.

Four major technological developments were examined. The technological developments selected for analysis were planting, fertilizer rates, insect control, and mechanical harvesting.

Problems regarding seeding rates and replanting were examined using marginal analysis and a budgeting technique. Results of the analysis of the seeding rate problem indicates that the seeding rate does not need to be increased because of plans to use stripper harvesting. Seed are inexpensive relative to cotton; therefore, farmers who plant for maximum yield are probably also maximizing net returns. Break-even yields and plant populations for replanting were computed; however, additional research is needed at low seeding rates and plant populations before definite conclusions regarding replanting can be made.

Production surfaces for fertilizer rates were determined using regression. Marginal analysis and a budgeting technique were used to evaluate the economic consequences of various fertilizer rates. Results from experiments at the Sandy Land Research Station near Mangum and at the Irrigation Research Station near Altus indicate that the application of nitrogen fertilizer is profitable; however, more research is needed before the optimum fertilizer strategy can be determined.

Game theory was suggested as a technique for analyzing the cotton insect problem. The data necessary for using game theory are not available, but a procedure for obtaining the data was outlined.

The budgeting technique was applied to mechanical harvesting data and the resulting net returns were discussed. The compatibility between normal net returns and various managerial goals was indicated. Defoliation increased returns in both of the two years that the experiment of plant preparation for picking irrigated cotton was conducted. For stripper harvesting of dryland cotton, none of the plant preparations increased net returns.

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A P P E N D I X

APPENDIX TABLE I

WEATHER DATA FOR THE CHICKASHA COTTON RESEARCH STATION, 1953-1961

	- Year -								
Month	1961	1960	1959	1958	1957	1956	1955	1954	1953
Jan.	.24	1.15	.07	1.40	.85	.44	1.34	.14	.28
Feb.	1.33	1.69	.67	.38	.96	.94	1.39	1.39	1.65
March	3.57	.64	1.48	2.65	3.03	.37	1.99	1.98	3.25
April	.55	.58	3.00	3.41	7.25	2.23	.70	4.98	2.77
May	2.51	7.29	8.13	2.23	9.71	4.23	10.27	5.25	1.91
June	3.71	2.25	1.87	5.88	5.85	2.42	1.69	1.29	1.91
July	7.77	4.76	9.80	2.63	.55	2.04	.40	Trace	5.01
Aug.	2.90	2.99	.94	3.87	.27	.55	5.29	.80	3.53
Sept.	8.08	.78	6.25	2.91	5.84	.02	5.41	.96	1.84**
Oct.	1.98	5.12	8.07	.13	2.76	4.44	5.01	2.99	6.87
Nov.	3.78	.05	.85	.48	2.40	1.51	0.00	.14	1.11
Dec.	1.17	2.63	2.57	.98	.74	1.99	.03	2.11	0.80
Yearly Total	37.35	29.93	43.70	26.95	40.21	21.18	33.52	22.03	30.93
Freeze Date	Oct. 26	-	Nov. 6	Oct. 28	Oct. 26	-	Nov. 3*	Oct. 29*	Nov. 9*

*Heavy Frost.

**Sept. 3, 1953 strong winds accompanied 1.55 inches of rain and damaged cotton.

Source: "Cotton Mechanization in Oklahoma."

APPENDIX TABLE II

COTTON YIELDS ON DRYLAND FERTILITY EXPERIMENTS, MANGUM, OKLAHOMA, 1959-1961

Treatment	1959 Yield Lint	1960 Yield Lint	1961 Yield Lint
	- lbs. per acre -		
0-0-0	319	486	383
0-20-0	430	604	--
0-40-0	327	482	--
20-0-0	399	691	--
20-20-0	446	698	614
20-40-0	425	674	706
40-0-0	489	761	595
40-20-0	430	818	729
40-40-0	423	873	735
60-0-0	471	892	818
60-20-0	480	955	891
60-40-0	511	1019	778
80-40-0	--	--	879*
60-60-0	--	--	773*
100-40-0	--	--	772*
80-20-0	--	--	757*

*New treatments in 1961.

Source: Reed, et al., "Cotton Fertilization Research Progress Report, 1960," p. 5, and Reed, et al., "Cotton Management and Fertility Research Progress Report, 1961," p. 10.

APPENDIX TABLE III

COTTON YIELDS ON DRYLAND FERTILITY EXPERIMENTS, CHICKASHA, OKLAHOMA, 1958-1961

Treatment	1958 Yield Lint	1959 Yield Lint	1960 Yield Lint	1961 Yield Lint
		- lbs. per acre -		
0-0-0	521	465	555	528
0-20-0	543	410	567	541
0-40-0	595	456	621	564
20-0-0	640	413	543	596
20-20-0	675	471	553	560
20-40-0	580	450	579	572
40-0-0	561	458	622	561
40-20-0	580	378	568	543
40-40-0	565	479	551	558
60-0-0	559	463	575	598
60-20-0	637	402	564	579
60-40-0	509	425	574	556
80-40-0	--	--	--	564*

*New treatment in 1961.

Source: Reed, et al., "Cotton Fertilization Research Progress Report, 1960," p. 3, and Reed, et al., "Cotton Management and Fertility Research Progress Report, 1961," p. 8.

APPENDIX TABLE IV

COTTON YIELDS ON IRRIGATED FERTILITY EXPERIMENT, ALTUS, OKLAHOMA, 1961

Treatment	1961 Yield Lint
	lbs. per acre
160-40-0	1135
160-80-0	1105
80-160-0	1104
80-40-0	1058
80-0-0	1042
80-80-0	1037
40-80-0	1028
40-40-0	990
0-0-0	727
0-80-0	663

Source: Reed, et al., "Cotton Management and Fertility Research Progress Report, 1961," p. 15.

APPENDIX TABLE V

COTTON YIELDS ON IRRIGATED FERTILITY EXPERIMENTS, CHICKASHA, OKLAHOMA, 1958-1961

Treatment	1958 Yield Lint	1959 Yield Lint	1960[1] Yield Lint	1961 Yield Lint
		- lbs. per acre -		
0-0-0	877	958	937	--
40-40-0	723	971	929	--
40-80-0	924	999	997	982
80-80-0	1010	1032	1047	1049
160-80-0	961	1036	978	980
80-40-0	828	1061	1064	992
80-160-0	808	979	1003	1120
160-40-0	976	1056	1069	1049
160-160-0	866[2]	997	1015	994
0-80-0	936	970	935	980
80-0-0	879	936	964	985
120-80-0	--	--	--	1006*
80-20-0	--	--	--	1024*

*New treatment in 1961.

[1]This column represents an adjusted yield for 1960. The stand was erratic and the skip count method was used to adjust yields.

[2]Treatment 9 was in 1958.

Source: Reed, et al., "Cotton Fertilization Research Progress Report, 1960," p. 7, and Reed, et al., "Cotton Management and Fertility Research Progress Report, 1961," p. 17.

APPENDIX TABLE VI

MARKET PRICE OF COTTON LINT AT LUBBOCK, TEXAS FOR MIDDLING LT. SPOTTED 15/16 (1961 THRU 1959); MIDDLING SPOTTED 15/16 (1958 THRU 1954)

Year	Aug.	September					October					November				December				
1961	29.35	29.35	29.55	30.35	30.35	31.10	31.10	31.10	31.25	31.35	[a]	31.35	31.25	31.25	31.10	31.10	30.85	30.15	29.90	29.90
1960	24.90	24.90	25.40	25.40	25.40	25.40	26.05	26.05	26.05	26.30	[a]	26.30	26.30	26.80	26.80	26.80	26.30	26.30	26.30	25.90
1959	[a]	[a]	[a]	25.80	25.80	[a]	25.80	25.80	26.55	27.05	27.25	27.25	27.25	26.75	27.00	27.00	27.00	27.00	27.50	27.50
1958	24.25	23.35	23.35	23.10	23.25	[a]	23.35	23.35	24.35	24.35	24.35	24.45	24.45	[a]	[a]	25.25	25.25	25.25	[a]	[a]
1957	24.90	24.95	25.00	25.15	25.15	[a]	24.85	24.95	25.20	24.95	24.70	24.95	25.45	24.95	[a]	24.45	24.20	24.20	24.20	[a]
1956	25.20	25.25	25.25	25.45	26.05	[a]	26.20	25.95	25.80	25.80	[a]	25.85	25.85	26.35	26.40	26.40	26.15	26.15	26.15	[a]
1955	28.55	28.50	28.30	27.60	27.60	27.55	26.75	27.80	28.20	29.35	[a]	29.35	29.35	29.35	[a]	29.35	29.35	29.35	29.35	29.35
1954	28.60	29.00	28.90	29.35	30.00	29.65	29.45	29.60	29.00	28.90	[a]	28.80	28.50	28.50	[a]	28.40	28.65	28.65	28.75	28.75
Total	185.75	185.30	185.75	212.20	213.60	113.70	213.55	214.60	216.40	218.05	76.30	218.30	218.40	193.95	111.30	218.75	217.75	217.05	192.15	141.40
No. of Years	7	7	7	8	8	4[b]	8	8	8	8	3[b]	8	8	7	4[b]	8	8	8	7	5[b]
Weekly Av.	26.54	26.47	26.54	26.52	26.70		26.69	26.82	27.05	27.26		27.29	27.30	27.71		27.34	27.22	27.13	27.45	
Over-all Av.	27.08																			
Seasonal Index	98.01	97.75	98.01	97.93	98.60		98.56	99.04	99.89	100.66		100.78	100.81	102.33		100.96	100.52	100.18	101.37	

[a]Information not reported or month had fewer reporting dates than other years.

[b]Data not reported in enough years to compute reliable index.

Source: Lubbock Market of "Spot Cotton Quotations," U.S. Department of Agriculture, AMS.

APPENDIX TABLE VII

MARKET PRICE OF COTTON LINT AT LUBBOCK, TEXAS FOR MIDDLING 15/16

Year	Aug.	September					October					November				December				
1961	30.65	30.65	30.85	31.40	31.65	31.90	31.90	32.10	31.85	31.75	a	31.75	31.75	31.75	31.60	31.60	31.60	31.35	31.35	31.85
1960	27.50	27.50	27.50	27.50	27.50	27.50	27.65	27.65	27.65	27.65	a	27.65	27.65	27.65	27.65	27.65	27.15	27.15	27.15	27.25
1959	29.75	29.75	29.75	29.75	29.75	a	29.75	29.75	29.50	29.00	29.00	29.00	29.00	28.75	29.00	29.00	29.00	29.00	29.50	29.50
1958	32.50	32.25	32.25	32.00	32.15	a	32.25	32.25	32.25	32.25	32.25	32.35	32.35	a	a	32.00	32.00	32.00	a	a
1957	30.75	30.80	30.85	31.00	31.00	a	30.70	31.25	31.50	32.10	31.85	32.10	32.60	32.35	a	32.10	32.35	32.35	32.35	a
1956	31.95	31.00	31.00	31.20	31.30	a	31.45	31.20	31.05	30.80	a	30.85	30.85	31.35	30.90	30.90	30.65	30.65	30.65	a
1955	32.80	32.75	32.55	31.85	31.85	31.80	31.00	31.80	32.20	33.30	a	33.30	33.30	33.30	a	33.30	33.30	33.30	33.30	33.30
1954	32.85	33.25	33.15	33.60	34.25	33.90	33.70	33.85	33.25	33.15	a	33.05	32.75	32.75	a	32.65	32.90	32.90	33.00	33.00
Total	248.75	247.95	247.90	248.30	249.45	125.10	248.40	249.35	249.25	250.00	93.10	250.05	250.25	217.90	119.15	249.20	248.95	248.70	217.30	154.90
No. of Years	8	8	8	8	8	4[b]	8	8	8	8	3[b]	8	8	7	4[b]	8	8	8	7	5[b]
Weekly Av.	31.09	30.99	30.99	31.04	31.18		31.05	31.23	31.16	31.25		31.26	31.28	31.13		31.15	31.12	31.09	31.04	
Over-all Av.	31.09																			
Seasonal Index	100.00	99.68	99.68	99.84	100.29		99.87	100.45	100.23	100.51		100.55	100.61	100.13		100.19	100.10	100.00	99.84	

[a] Information not reported or month had fewer reporting dates than other years.

[b] Data not reported in enough years to compute reliable index.

Source: Lubbock Market of "Spot Cotton Quotations," U. S. Department of Agriculture, AMS.

APPENDIX TABLE VIII

MARKET PRICE OF COTTON LINT AT LUBBOCK, TEXAS FOR MIDDLING 31/32

Year	Aug.	September					October					November				December				
1961	31.65	31.65	31.85	32.15	32.15	32.40	32.40	32.60	32.25	32.25	a	32.25	32.25	32.25	32.10	32.10	32.10	31.85	31.85	32.35
1960	28.50	28.50	28.50	28.50	28.50	28.50	28.65	28.65	28.65	28.65	a	28.65	28.65	28.65	28.65	28.65	28.15	28.15	28.15	28.25
1959	30.65	30.65	30.65	30.65	30.65	a	30.65	30.65	30.40	29.90	29.90	29.90	29.90	29.75	30.00	30.00	30.00	30.00	30.50	30.50
1958	33.40	33.15	33.15	32.90	33.05	a	33.15	33.15	33.15	33.15	33.15	33.25	33.25	a	a	32.90	32.90	32.90	a	a
1957	31.90	31.95	32.00	32.15	32.15	a	31.85	31.85	32.10	32.70	32.45	32.70	33.20	32.95	a	32.70	33.10	33.10	33.10	a
1956	31.95	31.00	31.00	31.20	31.30	a	31.45	31.20	31.05	30.80	a	30.85	30.85	31.35	30.90	30.90	30.65	30.65	30.65	a
1955	33.40	33.35	33.15	32.45	32.45	32.40	31.60	32.40	32.80	33.75	a	33.75	33.75	33.75	a	33.75	33.75	33.75	33.75	33.75
1954	33.10	33.50	33.40	33.85	34.50	34.15	33.95	34.35	33.75	33.65	a	33.55	33.25	33.25	a	33.15	33.40	33.40	33.50	33.50
Total	254.55	253.75	253.70	253.85	254.75	127.45	253.70	254.85	254.15	254.85	95.50	254.90	255.10	221.95	121.65	254.15	254.05	253.80	221.50	158.35
No. of Years	8	8	8	8	8	4[b]	8	8	8	8	3[b]	8	8	7	4[b]	8	8	8	7	5[b]
Weekly Av.	31.82	31.72	31.71	31.73	31.84		31.71	31.86	31.77	31.86		31.86	31.89	31.71		31.77	31.76	31.72	31.64	
Over-all Av.	31.74																			
Seasonal Index	100.25	99.94	99.91	99.97	100.32		99.91	100.38	100.09	100.38		100.38	100.47	99.91		100.09	100.06	99.94	99.68	

[a]Information not reported or month had fewer reporting dates than other years.

[b]Data not reported in enough years to compute reliable index.

Source: Lubbock Market of "Spot Cotton Quotations," U. S. Department of Agriculture, AMS.

APPENDIX TABLE IX

MARKET PRICE OF COTTON LINT AT LUBBOCK, TEXAS FOR STRICT LOW MIDDLING 15/16

Year	Aug.	September					October					November				December				
1961	29.35	29.35	29.55	30.25	30.25	31.00	31.00	31.00	31.00	31.40	a	31.40	31.30	31.30	31.15	31.15	30.80	30.10	29.85	29.85
1960	24.75	24.75	25.25	25.25	25.25	25.25	25.90	25.90	25.90	26.40	a	26.40	26.40	26.65	26.65	26.65	26.15	26.15	26.15	26.00
1959	26.55	26.55	26.50	26.50	26.50	a	26.50	26.50	26.25	25.75	26.00	26.00	26.00	26.00	26.25	26.25	26.25	26.25	26.25	26.25
1958	28.15	28.40	28.40	28.15	28.30	a	28.40	28.40	29.80	29.80	29.80	29.40	29.15	a	a	28.80	28.80	28.80	a	a
1957	28.00	28.05	28.10	28.25	28.25	a	27.95	28.05	28.30	28.60	28.65	28.60	29.10	28.60	a	28.35	28.35	28.35	28.65	a
1956	27.95	28.00	28.00	28.20	28.30	a	28.45	28.20	28.05	27.80	a	27.85	27.85	28.35	27.90	27.90	27.65	27.65	27.65	a
1955	31.30	31.25	31.05	30.35	30.35	30.30	29.50	30.30	30.70	31.80	a	31.80	31.80	31.80	a	31.80	31.80	31.80	31.80	31.80
1954	31.10	31.50	31.40	31.85	32.50	32.15	31.95	32.10	31.50	31.90	a	31.80	31.50	31.50	a	31.40	31.90	31.90	31.40	32.00
Total	227.15	227.85	228.25	228.80	229.70	118.70	229.65	230.45	231.50	233.45	84.45	233.25	233.10	204.20	111.95	232.30	231.70	231.00	201.75	145.90
No. of Years	8	8	8	8	8	4[b]	8	8	8	8	3[b]	8	8	7	4[b]	8	8	8	7	5[b]
Weekly Av.	28.39	28.48	28.53	28.60	28.71		28.71	28.81	28.94	29.18		29.16	29.14	29.17		29.04	28.96	28.88	28.82	
Over-all Av.	28.84																			
Seasonal Index	98.44	98.75	98.93	99.17	99.55		99.55	99.90	100.35	101.18		101.11	101.04	101.14		100.69	100.42	100.14	99.93	

[a] Information not reported or month had fewer reporting dates than other years.

[b] Data not reported in enough years to compute reliable index.

Source: Lubbock Market of "Spot Cotton Quotations," U. S. Department of Agriculture, AMS.

APPENDIX TABLE X

MARKET PRICE OF COTTON LINT AT LUBBOCK, TEXAS FOR STRICT LOW MIDDLING SPOTTED 15/16

Year	Aug.	September					October					November				December				
1961	27.45	27.45	27.65	27.95	27.95	28.20	28.20	28.20	28.20	28.30	a	28.30	28.55	28.75	29.10	29.10	28.75	28.25	27.90	27.90
1960	21.75	21.75	21.75	21.75	21.75	21.75	22.15	22.15	22.15	22.15	a	22.15	23.15	23.25	24.05	24.05	24.50	24.50	24.50	24.10
1959	a	a	a	20.00	20.00	a	20.00	20.00	20.75	21.25	21.75	21.75	21.75	21.00	22.00	22.00	22.00	23.00	23.50	23.50
1958	21.20	21.10	21.10	20.85	21.00	a	21.10	21.10	22.10	22.10	22.10	22.20	22.20	a	a	22.35	22.35	22.35	a	a
1957	23.15	23.20	23.25	23.40	23.40	a	23.10	22.70	22.95	22.15	22.20	22.15	22.65	22.15	a	21.65	21.40	21.40	21.70	a
1956	21.95	22.00	22.00	22.20	22.80	a	22.95	22.70	22.55	23.05	a	23.10	23.10	23.60	24.65	24.65	24.40	24.40	24.40	a
1955	27.30	27.25	27.05	26.35	26.35	26.30	25.50	26.30	27.20	27.40	a	27.40	27.40	27.40	a	27.40	27.40	27.40	27.40	27.40
1954	27.10	27.50	27.40	27.85	28.50	28.15	27.95	28.10	27.50	27.40	a	27.30	27.00	27.00	a	26.90	27.15	27.15	27.30	27.25
Total	169.90	170.25	170.20	190.35	191.75	104.40	190.95	191.25	193.40	193.80	66.05	194.35	195.80	173.15	99.80	198.10	197.95	198.45	176.70	130.15
No. of Years	7	7	7	8	8	4[b]	8	8	8	8	3[b]	8	8	7	4[b]	8	8	8	7	5[b]
Weekly Av.	24.27	24.32	24.31	23.79	23.97		23.87	23.91	24.18	24.22		24.29	24.48	24.74		24.76	24.74	24.81	25.24	26.03
Over-all Av.	24.44																			
Seasonal Index	99.30	99.51	99.47	97.34	98.08		97.67	97.83	98.94	99.10		99.39	100.16	101.23		101.31	101.23	101.51	103.27	

[a]Information not reported or month had fewer reporting dates than other years.

[b]Data not reported in enough years to compute reliable index.

Source: Lubbock Market of "Spot Cotton Quotations," U. S. Department of Agriculture, AMS.

APPENDIX TABLE XI

MARKET PRICE OF COTTON LINT AT LUBBOCK, TEXAS FOR STRICT LOW MIDDLING 31/32

Year	Aug.	September					October					November				December				
1961	29.85	29.85	30.05	30.75	30.75	31.50	31.50	31.50	31.50	31.60	a	31.65	31.55	31.55	31.40	31.40	31.05	30.35	30.35	30.60
1960	25.75	25.75	26.25	26.25	26.25	26.25	26.90	26.90	26.90	26.90	a	26.90	26.90	26.90	26.90	26.90	26.40	26.40	26.40	26.25
1959	27.25	27.25	27.40	27.40	27.40	a	27.40	27.40	27.15	27.65	26.90	26.90	26.90	27.00	27.25	27.25	27.25	27.25	27.75	27.75
1958	29.00	29.25	29.25	29.00	29.15	a	29.25	29.25	30.50	30.50	30.50	30.10	29.85	a	a	29.50	29.50	29.50	a	a
1957	28.15	28.20	28.25	28.40	28.40	a	28.10	28.20	28.45	29.20	28.95	29.20	29.70	29.20	a	28.95	28.95	28.95	28.95	a
1956	28.20	28.25	28.25	28.45	28.55	a	28.70	28.45	28.30	28.05	a	28.10	28.10	28.60	28.15	28.15	27.90	27.90	27.90	a
1955	31.90	31.85	31.65	30.95	30.95	30.90	30.10	30.90	31.30	32.30	a	32.30	32.30	32.30	a	32.30	32.30	32.30	32.30	32.30
1954	31.35	31.75	31.65	32.10	32.75	32.40	32.20	32.35	31.75	32.30	a	32.30	31.90	31.90	a	31.80	32.30	32.30	32.40	32.40
Total	231.45	232.15	232.75	233.30	234.20	121.05	234.15	234.95	235.85	238.50	86.35	237.35	237.20	207.45	113.70	236.25	235.65	234.95	206.05	149.30
No. of Years	8	8	8	8	8	4[b]	8	8	8	8	3[b]	8	8	7	4[b]	8	8	8	7	5[b]
Weekly Av.	28.93	29.02	29.09	29.16	29.28		29.27	29.37	29.48	29.81		29.67	29.65	29.64		29.53	29.46	29.37	29.44	
Over-all Av.	29.38																			
Seasonal Index	98.47	98.77	99.01	99.25	99.66		99.63	99.97	100.34	101.46		100.99	100.92	100.88		100.51	100.27	99.97	100.20	

[a]Information not reported or month had fewer reporting dates than other years.

[b]Data not reported in enough years to compute reliable index.

Source: Lubbock Market of "Spot Cotton Quotations," U. S. Department of Agriculture, AMS.

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Candidate for the Degree of

Master of Science

Thesis: AN ECONOMIC ANALYSIS OF SELECTED TECHNOLOGICAL DEVELOPMENTS IN COTTON PRODUCTION

Major Field: Agricultural Economics

Biographical:

Personal Data: Born near Granite, Oklahoma, December 7, 1938, the son of Bert and Minerva Williams.

Education: Graduated from Granite High School, Granite, Oklahoma, May, 1957; received the Bachelor of Science Degree from Oklahoma State University, Stillwater, Oklahoma, with a major in Agricultural Economics, in May, 1961; completed requirements for the Master of Science degree in May, 1963.

Professional Experience: Farmed cotton while in high school and an undergraduate in college; in 1956 won first in the state of Oklahoma in a Future Farmers of America cotton improvement contest; taught farm management laboratory at Oklahoma State University from January to May, 1962; was a research assistant, Oklahoma State University from June to October, 1962.