AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Journal of Agricultural and Resource Economics 22(1):157–173
Copyright 1997 Western Agricultural Economics Association

Cotton Cultivar, Planting, Irrigating, and Harvesting Decisions under Risk

James A. Larson and Harry P. Mapp

Producers in southwest Oklahoma lack adequate information about optimal planting decisions for cotton. This study uses a cotton growth simulation model to evaluate alternative cultivar, planting date, irrigation, and harvest choices. Effects of using information about soil moisture at reproduction and revenue loss at harvest in making cultivar and planting date decisions are evaluated. Using soil temperature information to plant at an early date produced high net revenue some years, but reduced mean net revenue and increased risk. Producers maximizing expected net revenue should plant a short-season cultivar in late May and use soil moisture information to schedule irrigations at reproduction.

Key words: cotton, production risk, risk premiums, simulation

Introduction

Southwest Oklahoma is at the northern edge of the "cotton belt" in the United States. Even with irrigation, cotton yields are highly variable due to extreme weather conditions and a short growing season (Verhalen, Bayles, and Thomas). Cotton growth and development depend on a number of production and management decisions (Banks, Williams, and Thomas). Historically, many producers in the area have planted a long-season cotton cultivar very early in the growing season, often in April. When weather conditions are favorable, including warm temperatures and timely rainfall, this planting strategy will produce excellent cotton yields and high net revenues. However, a soil temperature of 60°F is the minimum for germination and emergence. Thus, producers who plant early may have to replant one or more times. Multiple plantings increase costs and may result in lower net revenues. Extension cotton specialists in the area recommend that producers plant a short-season cultivar later in the growing season. They feel that while this strategy may not produce maximum yields, it is likely to produce higher expected net revenues. However, little research has been conducted to support this recommendation.

Other production and environmental factors influence expected yields and returns and must be considered when evaluating cultivars and planting dates. For example, for a given cultivar and planting date, the seeding rate influences expected yields and net revenues. Also, irrigation water from a Bureau of Reclamation reservoir in the area is not available until late June. Depending on cultivar, planting date, and seeding rate decisions, the cotton plant will be at different stages of development when irrigation water

---

Larson is assistant professor, Department of Agricultural Economics and Rural Sociology, The University of Tennessee, Knoxville; Mapp is regents professor and Jean and Patsy Neustadt Chair, Department of Agricultural Economics, Oklahoma State University, Stillwater.

The authors gratefully acknowledge the helpful comments of Odell Walker, Francis Epplin, Roland Roberts, Anne Jeager, and several anonymous reviewers on earlier drafts of this manuscript. We accept full responsibility for remaining errors or omissions.

becomes available. Thus, choice of cultivar and planting date may be influenced by when irrigation water becomes available. Further, different cultivars mature at different rates and have different harvest dates. Late in the growing season, unfavorable weather can reduce the yield and quality of cotton harvested. Thus, the potential reductions in cotton quality and price associated with late harvest also interact with cultivar, planting date, and seeding rate decisions. However, even less research has been conducted to evaluate these interactions or their impacts on cultivar choice, planting date, cotton growth and development, and net revenue risk.

The objective of this study is to evaluate alternative cultivar, planting, irrigating, and harvesting choices as to how they affect the expected value and variability of net revenues from cotton production. Three information scenarios, referred to as nonupdated, updated, and revised, are evaluated. The revised and updated information is that used to schedule irrigations and determine yield and quality losses at harvest due to adverse weather. Finally, a producer's attitude toward risk may also influence cultivar choice and planting decisions. Thus, decisions are evaluated for producers who are risk neutral, extremely risk averse, and risk preferring.

The setting for the analysis is an irrigated cotton enterprise in the Lugert-Altus Irrigation District. Yields from farms or from field experiments in the study area are inadequate for evaluating production risk because the data do not include information about cultivar and planting decisions, or plant growth and development events that influenced yield. We use a cotton growth simulation model adapted to the locale to estimate production risk. The model has mathematical functions of physical and biological processes that are linked to simulate daily plant growth and development (King et al.; Whisler et al.). The three information scenarios used to simulate yields and net revenues depict the use of calendar date versus soil moisture information for scheduling irrigations and constant versus variable yield and quality losses at harvest to revise cultivar, planting date, and seeding rate decisions.

We determine for each information scenario the cultivar, planting, irrigating, and harvesting decisions that maximize expected net revenue, maximize the minimum net revenue (maximin strategy), and maximize the maximum net revenue (maximax strategy). Generalized stochastic dominance is used to estimate the value of certain information for decision makers whose risk attitudes are represented by maximizing, maximin, and maximax strategies.

The Decision Environment

Cotton growth and development includes germination, emergence, seedling growth, reproduction, and maturation. After emergence, the plant produces a series of recognizable joints on the main stem called main-stem nodes. Fruit which becomes cotton bolls develops on branches that grow outward from each main-stem node. The appearance of the first fruiting branch, marking the beginning of reproduction, depends on cultivar, plant population, and the environment (Jackson, Arkin, and Hearn). Additional main-stem nodes and fruiting branches continue to develop above the first fruit branch until growth is terminated and the crop is harvested.

Assume that the decision problem involves the timing of three sequential choices that coincide with critical growth and development events: planting followed by germination,

emergence, and seedling growth; irrigating at reproduction; and harvesting after maturation. A farmer must choose a cultivar before planting. This decision requires matching cultivar maturity with expected season length and considering the effects of cultivar growth and development on irrigation and harvest decisions after planting. Short-season cultivars start reproduction earlier, generate fruit at a faster rate, and produce fruit for a shorter time than medium-season and long-season cultivars.

Following Antle and Hatchett, the carryover effects of the cultivar decision on planting (x_1), irrigating (x_2), and harvesting (x_3) can be represented by stage-level production functions:

$$y_1 = f_1(\eta, x_1, \theta_1) \quad \text{and} \tag{1}$$

$$y_t = f_t(x_t, y_{t-1}, \theta_t) \quad \text{for } t = 2, 3, \tag{2}$$

where y_t is the current crop state, η is the cultivar decision made before planting, x_t is choice t in the decision sequence, θ_t is a random production event after decision t, y_{t-1} is previous crop state resulting from x_{t-1} and θ_{t-1}. Recursive substitution of y_1 and y_2 into y_3 produces the composite production function:

$$y_3 = F(\eta, x_1, x_2, x_3, \theta_1, \theta_2, \theta_3) \quad \text{where} \quad \begin{cases} x_1 = g(\eta) \\ x_2 = h(\eta) \\ x_3 = i(\eta), \end{cases} \tag{3}$$

and y_3 is assumed to be strictly concave. Totally differentiating the function yields

$$dy_3 = f_\eta d\eta + f_1 dx_1 + f_2 dx_2 + f_3 dx_3 + f_{\theta 1} d\theta_1 + f_{\theta 2} d\theta_2 + f_{\theta 3} d\theta_3. \tag{4}$$

Let $d\theta_t = 0$, $f_t = \partial y_3/\partial x_t$ for $t = 1, 2$, and 3, and $f_\eta = \partial y_3/\partial \eta$. Division of dy_3 by $d\eta$ produces

$$\frac{dy_3}{d\eta} = \frac{\partial y_3}{\partial \eta} + \frac{\partial y_3}{\partial x_1}\frac{dx_1}{d\eta} + \frac{\partial y_3}{\partial x_2}\frac{dx_2}{d\eta} + \frac{\partial y_3}{\partial x_3}\frac{dx_3}{d\eta}. \tag{5}$$

This result illustrates the effects of cultivar on planting, irrigating, and harvesting decisions. Cultivar decision η directly influences yield through the cultivar's reproductive characteristics. For example, a long-season cultivar has the greatest yield potential; however, a short-season cultivar can produce a higher yield when heat units are a limiting factor of production (Waddle). Cultivar also interacts with planting date, other planting decisions, and subsequent weather events to influence irrigation and harvest decisions. Irrigation and harvest decisions and production risk become partially endogenous because of the growth and development pattern determined by cultivar and planting decisions.

Modeling the Cotton Decision Environment

We used a process cotton simulation model (Jackson, Arkin, and Hearn) and daily weather data from the study area to simulate yields. The cotton model was adapted to reflect the effects of soil type, cultivar choice, and plant population on first fruiting branch, reproduction, and yield for alternative planting dates and irrigation strategies. Methods used to adapt and validate the model to the study area are presented in Larson et al.

Planting Stage

Three cotton cultivars representing different maturities were modeled and evaluated: long-season (Acala types), medium-season (Delta types), and short-season (Plains types). To represent the planting decision, two planting criteria were simulated. The first assumes the producer plants on a given calendar date, for example, 17 May, each year. On 17 May in the study area, soil temperature averages 65°F, but varies from 52 to 76°F. Four other calendar dates ranging from 19 April to 14 June are also evaluated. Later planting dates have a higher probability of soil temperature above 60°F, the minimum for germination and emergence, but shorten the expected length of the growing season. If conditions remain favorable after an early planting date, the crop has a longer expected growing season and a higher expected yield. However, soil temperature may fall below 60°F following planting and thus delay or prevent emergence and seedling growth.

The second planting criterion uses a 10-day moving average of minimum soil temperature 4 inches below the soil surface to determine the planting date. For example, planting is assumed to occur when the 10-day moving average of soil temperature rises to 65°F. Using this criterion, simulated planting dates range from 6 April to 14 June. In addition, 10-day moving averages of minimum soil temperature 4 inches below the soil surface of 60° and 70°F are also evaluated.

In cotton production, the seeding rate varies with planting date. A higher seeding rate is optimal at earlier planting dates, and a lower rate is optimal later in the season. Further, plant population survival varies with seeding rate, planting date, and weather conditions. Plant population survival as a percentage of the seeding rate for each planting date was generated from a truncated lognormal distribution that is conditional on planting date soil temperature (table 1). As soil temperature rises at later planting dates, plant survival increases toward a 60% maximum (Verhalen and Williams). Excessive plant populations (from too high a seeding rate) delay reproduction, reduce yield, and increase costs.

Reproduction Stage

Cotton in the Lugert-Altus Irrigation District is furrow irrigated through a canal system fed from a Bureau of Reclamation reservoir. Producers' annual allocation varies from 6 to 24 acre-inches per irrigated acre, with a modal value of 18 acre-inches per acre (Kirby). Because of limited rainfall, irrigation water is generally not available until late June when temperatures and crop water demands are already high. Farmers know the total allocation they will receive for the season by mid-June. Cultivar and planting decisions may be impacted by the date at which irrigation water becomes available. In this analysis, producers are assumed to have an annual irrigation allocation of 16 acre-inches per acre, and that allocation is available beginning 28 June. The allocation can be maintained in a water-short year either by adjusting acreage or purchasing allocation, and we assumed the farmer purchases allocation when needed.

Harvest Stage

After cotton bolls mature, yield and quality losses occur due to adverse weather conditions (Williford). The simulation model calculates the yield and maturity date but does not estimate losses due to weathering before harvest. Yield and quality at harvest were

Table 1. Information Used to Simulate Cultivar, Planting, Irrigating, and Harvesting Decisions

Information Solution	Decision Stage		
	Planting Stage	Reproduction Stage	Harvest Stage
Nonupdated	Calendar or soil temperature: Cultivar maturity type[a] Initial planting date[b] Number of replantings[c] Plant population survival[d] Seeding rate[e]	Irrigation: Available 28 June 16 ac.-in. allocation 4 ac.-in. applied on a 2-week schedule	Constant revenue loss: $0.02/lb. discount 6% yield loss
Updated	Calendar or soil temperature: Nonupdated decisions	Irrigation: Same as above except scheduled using soil moisture information[f]	Revenue loss: Updated using actual distribution
Revised	Calendar or soil temperature: Revised using information about reproduction and season length	Irrigation: Revised using information about reproduction and season length	Revenue loss: Revised using actual distribution

[a] Short (Plains types), medium (Delta types), and long (Acala types) season cultivars.
[b] Calendar planting dates were 19 April, 3 May, 17 May, 31 May, and 14 June. Soil temperatures planting dates were 60, 65, and 70°F 10-day moving averages of daily minimum soil temperature at four inches.
[c] Average number of plantings for the respective calendar planting dates were 1.26, 1.10, 1.05, 1.00, and 1.00. Average number of plantings for the respective soil temperature planting dates were 1.25, 1.12, and 1.05.
[d] Average plant population survival as a percentage of the seeding rate for the respective calendar planting dates were 32, 42, 46, 51, and 55% and for the respective soil temperatures planting dates were 39, 46, and 55%.
[e] Seeding rates for the respective calendar planting dates were 60, 80, 100, 120, 140, or 160 thousand seed/ac. Seeding rates were 105, 118, 132, 145, and 158 thousand seed/ac. for the 60°F planting date; 87, 98, 108, 119, and 130 thousand seed/ac. for the 65°F planting date; and 74, 83, 92, 101, and 110 thousand seed/ac. for the 70°F planting date.
[f] Soil moisture irrigation schedule: 20, 25, 30, 35, and 40% of plant-available water.

modeled as a function of rainfall between maturity and harvest. The equation estimated from data by Williford used to calculate lint yield (lb./ac.) at harvest (Y_{LH}) is

$$(6) \quad Y_{LH} = Y_{Maturity}\,(\underset{(61.4)}{0.97} - \underset{(4.9)}{6.74} \times 10^{-4} RAIN) \qquad \text{adjusted } R^2 = 72,\ n = 10,$$

where $Y_{Maturity}$ is simulated lint yield at maturity (lb./ac.) and *RAIN* is rainfall between the dates of maturity and harvest. The *t*-statistics are in parentheses. Cottonseed yield at harvest (Y_{SH}) was reduced by the same proportion as Y_{LH} for calculating net revenues. The equation used to estimate lint price ($/lb.) at harvest ($P_{LH}$) is

$$(7) \quad P_{LH} = P_{BASE}\,(\underset{(36.1)}{0.98} - \underset{(2.7)}{4.52} \times 10^{-4} RAIN) \qquad \text{adjusted } R^2 = 60,\ n = 5.$$

Price discounts used to estimate P_{LH} were from the 1992 Commodity Credit Corporation

(CCC) loan schedule (U. S. Department of Agriculture). The assumed cotton base price (P_{BASE}) was \$0.60/lb.[1] Cottonseed price at harvest (P_{SH}) was assumed unaffected by precipitation (\$0.04/lb.).

The means for yield losses and quality losses estimated across nonupdated planting strategies were used to calculate net revenues for each element of the nonupdated information distributions. Nonupdated harvested yields were calculated by multiplying maturity date yields by 0.94 (mean yield loss of 6%). The nonupdated lint price at harvest, P_{LH}, was a constant \$0.58/lb. (mean quality loss of \$0.02/lb.). For the updated and revised information scenarios, the estimated yield and quality losses in each weather year were used to calculate net revenue in that year.

Estimating Net Revenue

In the analysis, cotton yields and net revenues are simulated for a number of strategies based on 43 years of daily weather data from the study area (U.S. Department of Commerce). The equation used to calculate net revenue (NR) for the cotton enterprise is

$$(8)\quad NR = (P_{LH}Y_{LH} + P_{SH}Y_{SH})PLTAC + GPAY - (VC_{PLT}PLTNO + VC_{IRRG}IRRGNO + VC_{HARV}Y_{LH} + VC_{OTHER})PLTAC,$$

where *PLTAC* is planted acreage, *GPAY* is a government program payment, VC_{PLT} is planting cost (\$/ac.), *PLTNO* is the number of planting operations required to establish the stand, VC_{IRRG} is irrigation cost (\$/ac.), *IRRGNO* is the number of irrigations, VC_{HARV} is harvest cost (\$/lb.), and VC_{OTHER} are costs not influenced by planting, irrigating, and harvesting decisions.

Parameters from a budget for furrow-irrigated cotton were used to estimate planting and other costs (Walker and Kletke). VC_{PLT} was influenced by the seeding rate (\$1.33/10,000 seeds/ac.) and *PLTNO* (\$6.02/ac./planting for machinery, labor, and materials). For both the calendar and soil moisture planting date criteria, the crop was assumed replanted and additional costs incurred if the crop model did not predict emergence within 14 days after planting. This assumption is consistent with extension recommendations for the study area (Banks, Williams, and Thomas). Average *PLTNO* increases with earlier planting dates reflecting lower and more variable soil temperatures (table 1). VC_{IRRG} included charges for water (\$2.08/ac.-in.) and labor (\$3.29/ac./irrigation). Irrigation costs were constant for the calendar date irrigation schedule but were dependent on the number of irrigations when initiated based on soil moisture. Harvest cost (VC_{HARV}) was \$0.22/lb. of lint harvested.

Other variable costs (VC_{OTHER} of \$162) kept constant in the simulation were for land preparation, irrigation district fees and expendable tools, insecticides, midseason tillage, and harvest aid. Yield losses from insects at reproduction were assumed to be 15% (Jackson, Arkin, and Hearn), along with costs for five insecticide applications (Walker

[1] Average cash price received, less storage and interest charges, if cotton were sold on the same business day each year, between 1 November and 1 June 1973–91 (Anderson, Sahs, and Felty). The crop was assumed to be put under government loan after harvest and sold at the same later date each year. Quality loss from weathering is primarily reflected in grade deterioration, predominately from increased grayness and yellowness in the fiber.

and Kletke). *PLTAC* is assumed to be 325 acres (Walker). *GPAY* is an expected government program payment of $26,860.[2]

Analysis of the Decision Problem

Three information scenarios, identified as nonupdated, updated, and revised, are used to analyze cultivar, planting date, seeding rate, irrigation, and harvesting decisions. Yields and net revenues are simulated for the long-season, medium-season, and short-season cotton cultivars. For each cultivar, five calendar planting date and three 10-day moving average, soil temperature, and planting date alternatives are considered. Six seeding rates associated with each of six calendar planting dates are simulated. Also simulated are five rates for each soil-temperature planting date using mean plant survival at that temperature. The information which varies by scenario is that used to schedule irrigation at reproduction and weather related yield and quality losses at harvest.

Information Scenarios

Nonupdated Information. The nonupdated information scenario uses a set calendar date to schedule irrigations at reproduction and constant yield and quality loss percentages at harvest for each cultivar, planting date, and seeding rate alternative. The set calendar date for initiating irrigations is 28 June, when the irrigation allocation becomes available, and four irrigation applications of four acre-inches each are applied on a two-week schedule. The 135 net revenue distributions estimated under the nonupdated information scenario are searched to identify strategies that maximize expected net revenue. A decision maker who maximizes expected net revenue is considered risk neutral. To represent other risk attitudes, the distributions are also searched to identify strategies which maximize the minimum net revenue (a maximin strategy) and maximize the maximum net revenue (a maximax strategy). Maximin and maximax decision criteria are consistent with extreme risk aversion and extreme risk preference (Grube).

Updated Information. The updated information scenario uses five threshold criteria for percentage of plant-available water to schedule irrigations at reproduction and uses rainfall after maturity to predict yield and quality losses at harvest. The five threshold criteria are 20, 25, 30, 35, and 40% of plant-available water, and these are used to schedule up to four irrigation applications of four acre-inches per acre. The objective is to identify the plant-available water threshold that distributes the limited allocation of irrigation water during reproduction such that it maximizes expected net revenue. This search was repeated to identify the plant-available water thresholds which maximize the minimum net revenue and maximize the maximum net revenue.

---

[2] Government cotton program mechanics are such that payments (deficiency and loan deficiency) are determined using the county program yield and the base acreage. Because market price influences on net revenue were not considered (and their subsequent impact on the deficiency payment), payments were treated as an expected lump sum. The payment of $26,850 (1986–93 program average) was added to each net revenue outcome. Market price is an important source of risk faced by producers. The source of output price risk examined in this analysis is variability in final lint quality due to the production strategy.

Revised Information. The revised information scenario relaxes the assumption of a 28 June availability date for the irrigation allocation and allows irrigation applications up to two weeks earlier (14 June) when the soil is dry. The earlier irrigation date is used to evaluate potential interactions among cultivar choice, an earlier start of reproduction for earlier planting dates, soil moisture information, and information on yield and quality losses at harvest. Different strategies may be identified due to higher net revenue from planting earlier using a long-season cultivar, irrigating earlier using soil moisture information, or changing the seeding rate because of plant population and soil moisture interactions.

Stochastic Dominance Analysis

Net revenue was analyzed using generalized stochastic dominance (GSD) (Goh et al.). GSD ranks choices for decision makers with coefficients of absolute risk aversion (r) in the interval r_1, r_2. Different levels of risk aversion are modeled by varying r_1 and r_2. Analytical limits on r were determined using simulated maximin and maximax strategies because elicited values were not available (Grube).[3] The five r_1, r_2 intervals within these approximate bounds that were used to analyze net revenue are −0.0002 to −0.00005 (risk seeking), −0.00005 to 0.0001 (nearly risk neutral), 0 to 0 (risk neutral), 0.0001 to 0.0003 (risk averse), and 0.0003 to 0.0015 (extremely risk averse) (Bosch and Eidman). GSD calculates risk premiums (π) decision makers in these intervals are willing to pay to obtain a dominant distribution over a comparison distribution. Assume that the dominant distribution, Q, is generated using the nonupdated, updated, or revised information scenarios. Distribution T is the comparison strategy. The following mathematical calculations are performed:

$$\min \pi \exists\ EU(Q-\pi) - EU(T) < 0\ \forall\ U \in u, \quad \text{and} \tag{9}$$

$$\min \pi \exists\ EU(Q-\pi) - EU(T) \leq 0 \quad \text{for at least one } U \in u, \tag{10}$$

where EU is expected utility, u denotes admissible set of utility functions, U denotes individuals' utility function (Cochran and Raskin). Equation (9) gives the lower-bound π all individuals in (r_1, r_2) are willing to pay for the dominant strategy. Equation (10) gives the upper-bound π that at least one person is willing to pay. GSD was used to estimate risk premiums for maximin, maximax, and other strategies compared with maximizing expected net revenue.

Results and Discussion

In the analysis, the information used to schedule irrigations and to make harvest decisions after making alternative cultivar and planting date decisions had different effects on plant growth, development, and production risk. Consequently, net revenue and lower-bound

[3] Assuming normality to establish the distributional bound (McCarl and Bessler), then $r(X) = 2Z_\alpha/2\sigma_{net\ revenue}$, where Z_α=one-tailed value from the standard normal table, α=0.005, and $\sigma_{net\ revenue}$ = standard deviation of net revenue. Maximin revised: $0-\alpha = -0.995$, $Z_\alpha=2.57$, and $r(X) = 5.14/16{,}265=0.00032$. Maximax revised: $1-\alpha = 0.995$, $Z_\alpha=-2.57$, and $r(X)=-5.14/35{,}579= -0.00015$. Using Chebyshev's inequality as a less restrictive assumption to formulate the bound (McCarl and Bessler), then $r(X)\leq 2\alpha^{-0.5}/\sigma_{net\ revenue}$, where α=0.005 and $\sigma_{net\ revenue}$ =standard deviation of net revenue. Maximin revised: $r(X)=28/16{,}265=0.0017$.

risk premiums for the nonupdated, updated, and revised information scenarios are reported for calendar and soil temperature planting date (PD) criteria. Maximizing expected net revenue and risk premium results are presented first followed by net revenues and risk premiums for maximin and maximax decision criteria.

Maximizing Expected Net Revenue

Nonupdated Information Scenario. Of the 135 net revenue distributions estimated using yields simulated with the calendar date irrigation schedule, the 31 May PD using the short-season cultivar and 100,000 seed/ac. maximized expected net revenue. Mean net revenue is $82,060 compared with $75,568 for the best soil temperature PD which used the 65°F criterion, the short-season cultivar, and 108,000 seed/ac. (table 2). Planting medium-season and long-season cultivars at earlier planting dates and using higher seeding rates than for the 31 May PD also produced less net revenue and increased risk. For example, the strategy that maximized mean net revenue ($71,100) for medium-season cultivar used the 17 May PD and 120,000 seed/ac.

Two important factors influencing nonupdated net revenue are (*a*) the timing of reproduction with water availability from the irrigation district, and (*b*) the use of a predetermined calendar date schedule after irrigation is started. The beginning of reproduction and irrigation water availability (28 June) coincided best for the 31 May PD. The earliest simulated start of reproduction was 1 July, and the average was 5 July with a standard deviation of four days. Using calendar PDs earlier than 31 May resulted in earlier reproduction and the mistiming of fruit development relative to the calendar date irrigation schedule. For the soil temperature PD criteria of 65°F, two-thirds of the reproduction start dates were up to four weeks before 28 June with many of the planting dates occurring several weeks earlier than 31 May. Higher crop water demand due to earlier reproduction and dry soils in some years caused moisture stress before irrigation was available. Moreover, once water was available, the timing of irrigations using the predetermined calendar date schedule did not match crop water demand at reproduction. The mistiming of irrigation with earlier reproduction caused more low net revenue outcomes for the soil temperature PD. Lower plant population survival and the costs of replanting also influencing net revenue for the earlier calendar PDs and the 65°F PD. Lower plant survival resulted in a higher seeding rate and planting cost to achieve similar average plant populations.

The 31 May PD also dominates the 65°F PD in the risk averse [0.0001 to 0.0003] and extremely risk averse [0.0003 to 0.0015] absolute risk aversion intervals. The 31 May PD is less risky than the 65°F PD because net revenue is larger at each cumulative frequency level except for the very highest levels (figs. 1A and 1B). Risk neutral and risk averse farmers would not be willing to pay for soil temperature PD information when information about soil moisture at reproduction and revenue losses at harvest are not considered. The risk premiums required for decision makers in the two risk averse intervals to be indifferent between the two planting criteria are $6,094 and $3,923, respectively (table 3).

Updated Information Scenario. The 31 May PD and 65°F PD decisions that maximized expected net revenue for the nonupdated scenario were simulated using the five threshold criteria for percentage of plant-available water irrigation schedules starting 28 June (table 1). Net revenue was recalculated using the updated yields and predicted revenue losses at harvest in each year. For the 31 May PD, initiating irrigations when plant-available

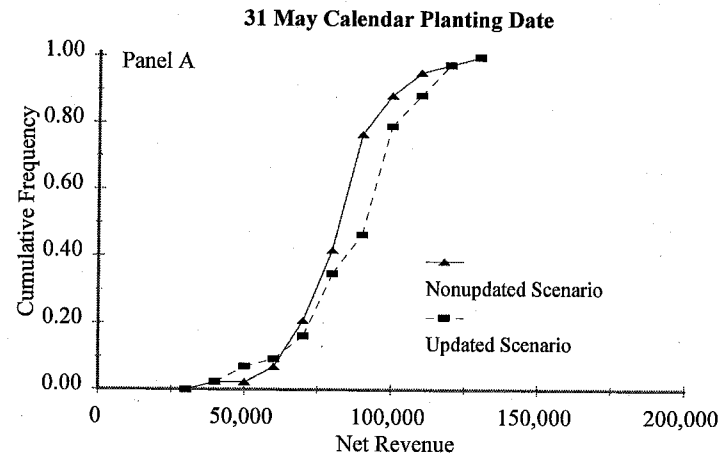
Table 2. Maximizing Expected Value, Maximin, and Maximax Net Revenues for Calendar and Soil Temperature Planting Date Strategies

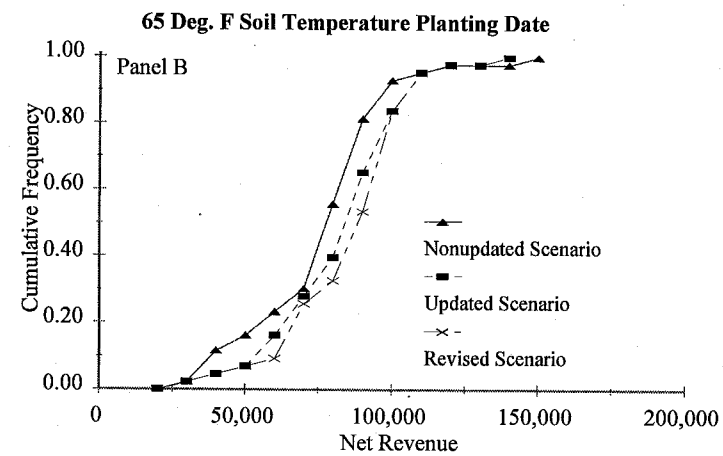
Risk Objective/ Planting Date	Information Scenario	Mean	Minimum	Maximum	Standard Deviation
Maximizing expected net revenue		(dollars)			
31 May	Nonupdated[a]	82,060	33,089	123,429	16,435
	Updated[b]	86,562	32,147	125,947	19,884
	Revised[c]	—[c]	—[c]	—[c]	—[c]
65°F	Nonupdated[d]	75,568	29,309	145,362	23,674
	Updated[e]	81,072	29,895	135,683	21,223
	Revised[f]	84,924	22,616	135,630	21,076
Maximin					
31 May	Nonupdated[g]	69,825	40,740	122,439	15,021
	Updated[h]	73,112	34,666	123,207	19,821
	Revised[i]	71,847	39,501	126,255	16,265
65°F	Nonupdated[j]	74,456	30,209	143,559	22,990
	Updated[k]	77,727	30,499	147,952	25,850
	Revised[c]	—[c]	—[c]	—[c]	—[c]
Maximax					
17 May	Nonupdated[l]	76,603	11,706	150,148	22,270
	Updated[m]	55,596	9,928	161,243	27,491
	Revised[c]	—[c]	—[c]	—[c]	—[c]
60°F	Nonupdated[n]	73,217	7,587	145,717	27,589
	Updated[o]	81,844	17,423	168,959	34,013
	Revised[p]	81,653	12,198	176,353	35,579

[a] Short-season cultivar, 100,000 seed/ac., and calendar date irrigated starting 28 June.
[b] Nonupdated planting decisions simulated using a 25% threshold of plant-available water.
[c] No strategy identified that improved on updated information scenario risk objective net revenue.
[d] Short-season cultivar, 108,000 seed/ac., and calendar date irrigated starting 28 June.
[e] Nonupdated planting decisions simulated using a 25% threshold of plant-available water.
[f] Updated decision set revised using 25% threshold of plant-available water starting 14 June.
[g] Short-season cultivar, 60,000 seed/ac., and calendar date irrigated starting 28 June.
[h] Nonupdated planting decisions simulated using 25% threshold of plant-available water.
[i] Updated decision set revised using 100,000 seed/ac. and 20% threshold of plant-available water.
[j] Short-season cultivar, 98,000 seed/ac., and calendar date irrigation starting 28 June.
[k] Nonupdated planting decisions simulated using 25% threshold of plant-available water.
[l] Short-season cultivar, 140,000 seed/ac., and calendar date irrigated starting 28 June.
[m] Nonupdated planting decisions simulated using 35% threshold of plant-available water.
[n] Short-season cultivar, 118,000 seed/ac., and calendar date irrigated starting 28 June.
[o] Nonupdated planting decisions simulated using 30% threshold of plant-available water.
[p] Updated decision set revised using 132,000 seed/ac. and 30% threshold of plant-available water.

water reached 25% improved mean net revenue by $4,502 to $86,562 (table 2). Net revenue shifted to the right at all cumulative frequency levels except for the lowest and highest levels (fig. 1A).

Using a 25% plant-available water threshold to update the 65°F PD improved mean net revenue by $5,504 to $81,072 and shifted net revenue to the right for many cumulative frequency levels (fig. 1B). Net revenues for the 65°F PD are still more variable than for the 31 May PD when using the updated information scenario after planting.





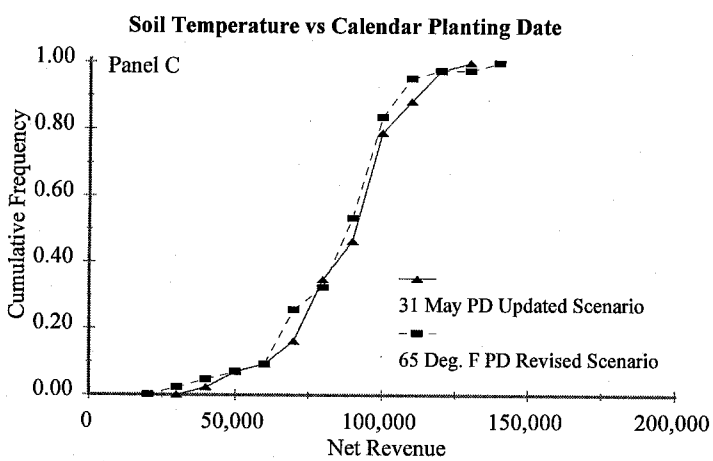


Figure 1. Maximizing expected net revenue calendar and soil temperature planting date (PD) strategies

Table 3. Risk Premiums for the Maximax and Maximin Strategies Compared with Maximizing Expected Net Revenue

Information Scenario/Risk Objective	Range of Absolute Risk Aversion				
	−0.0002 to −0.00005	−0.00005 to 0.0001	0 to 0	0.0001 to 0.0003	0.0003 to 0.0015
	(dollars)				
Nonupdated:[c]					
65°F PD net revenue maximum	2,874	N.D.[b]	(6,492)[a]	(6,094)[a]	(3,923)[a]
17 May PD maximax	4,582	N.D.[b]	(5,457)[a]	(18,781)[a]	(21,381)[a]
60°F PD maximax	4,117	N.D.[b]	(8,843)[a]	(25,529)[a]	(25,502)[a]
31 May PD maximin	(1,830)[a]	(4,009)[a]	(12,235)[a]	N.D.[b]	6,600
Updated:[c]					
65°F PD net revenue maximum	N.D.[b]	(3,075)[a]	(5,490)[a]	(3,991)[a]	(2,357)[a]
17 May PD maximax	N.D.[b]	(1,892)	(30,966)[a]	(23,575)[a]	(22,220)[a]
60°F PD maximax	17,249	N.D.[b]	(4,718)[a]	(16,306)[a]	(14,726)[a]
31 May PD maximin	(4,445)	(6,411)[a]	(13,450)[a]	N.D.[b]	753
Revised:[d]					
65°F PD net revenue maximum	N.D.[b]	(550)[a]	(1,638)[a]	(8,340)[a]	(9,531)[a]
60°F PD maximax	20,647	N.D.[b]	(4,909)[a]	(20,686)[a]	(19,949)[a]
31 May PD maximin	(1,678)[a]	(3,080)[a]	(14,715)[a]	N.D.[b]	5,298

[a] The risk premiums reported are for the lower bound of that range of absolute risk aversion. Numbers in parentheses indicate that the strategy that maximizes expected net revenue is dominant for that range of absolute risk aversion.
[b] N.D. = No dominance for that range of absolute risk aversion.
[c] The 31 May planting date (PD) strategy that maximizes expected net revenue for the nonupdated information scenario is the comparison strategy.
[d] The 31 May planting date (PD) strategy that maximizes expected net revenue for the updated information scenario is the comparison strategy.

However, in a comparison of the two updated scenarios, the risk premiums for the risk averse and extremely risk averse intervals were smaller than for the nonupdated scenario, decreasing to $3,991 and $2,357, respectively (table 3). Scheduling irrigations using crop water demand instead of following a set calendar date at reproduction reduced the riskiness of using the 65°F PD to plant early. Risk neutral and risk averse farmers would still not be willing to pay for soil temperature information to plant early when combined with soil moisture and harvest revenue loss information.

Revised Information Scenario. Simulations using medium-season and long-season cultivars planted before 31 May under the revised information scenario lowered yields, reduced net revenue, and increased risk relative to the short-season cultivar planted 31 May.[4] Higher seeding rates were used to compensate for lower plant survival, and soil moisture information was used to schedule irrigations after the 14 June and 28 June availability dates. The dominance of the short-season cultivar in the simulation is consistent with Larson et al., who found that later maturing cultivars yielded less in an analysis of 15 years of cultivar data from the study location. The growing season in

[4] These simulations included the 17 May PD using the 120,000 seed/ac. rate and short-season, medium-season, and long-season cultivars; and the 65°F PD using the 108,000 seed/ac. rate and medium-season and long-season cultivars.

southwest Oklahoma is not long enough to take advantage of potential interaction among later maturing cultivars (with a greater yield potential), early planting dates, plant population, and soil moisture information.

In this portion of the analysis, results for the 65°F PD criterion under the updated scenario are revised by allowing irrigation earlier (14 June) but still scheduling irrigations when plant-available water reached 25%. This strategy further improved mean net revenue to $84,924 (table 2; fig. 1B). Average yield was almost identical to the 31 May PD updated scenario, but the added costs of replanting and the higher seeding rates account for the lower net revenue. The cumulative frequency distributions of net revenue for the two strategies are similar, but the 65°F PD is still risker (fig. 1C). In a comparison with the 31 May PD updated scenario, the risk premiums required for decision makers in the risk averse and extremely risk averse intervals to be indifferent increased to $8,340 and $9,531, respectively (table 3). One reason for the increased risk with earlier irrigations is a water shortage and the resulting moisture stress in some years due to exhausting the irrigation allocation.

Maximin and Maximax Decision Criteria

Nonupdated Information Scenario. As with the maximizing expected net revenue decision criterion, soil temperature PDs were risk inefficient compared with calendar PDs when using maximin and maximax decision criteria (table 2). The risk premium that risk seeking decision makers [−0.0002 to −0.00005] are willing to pay for the 17 May PD maximax strategy is $4,582 compared with $4,117 for the 60°F PD maximax strategy (table 3). The risk premium that extremely risk averse decision makers are willing to pay for the maximin strategy is $6,600 (31 May PD, short-season cultivar, and lowest seeding rate of 60,000 seed/ac).

Updated Information Scenario. For the maximax decision criteria, the use of soil moisture and harvest revenue loss information improved the risk efficiency of the 60°F PD decisions relative to the 17 May PD decisions (figs. 2A and 2B). For the 60°F PD, scheduling irrigations when plant-available water reached 30% produced a large positive effect on net revenue for the higher cumulative frequency levels. The frequency of net revenue exceeding $100,000 is 30% compared with 21% for the expected net revenue maximizing 31 May PD simulated using the updated scenario (figs. 1A and 2B). Mean net revenue for the 60°F PD increases by $8,627 to $81,844 but is still $4,718 less than for the 31 May PD (table 2). The 31 May PD has stochastic dominance over the maximax strategy in all absolute risk aversion intervals except the near risk neutral [−0.00005 to 0.0001] and risk seeking intervals. The risk premium that risk seeking decision makers are willing to pay for the 60°F PD compared with maximizing net revenue rises from $4,117 for the nonupdated scenario to $17,249 for the updated scenario. Compared with the nonupdated scenario, updating the 31 May PD maximin decisions using soil moisture and harvest loss information did not improve minmum net revenue.

Revised Information Scenario. For the 60°F PD maximax strategy, use of revised seeding rate information increased maximum net revenue to $176,356 (132,000 seeds/ac.) (table 2; fig. 2B). The frequency of net revenue exceeding $100,000 increased to 33%. The increased riskiness of the 60°F PD compared with maximizing net revenue is illustrated in fig. 2C. Larger net revenues in the "good" growing years were insufficient to offset lower yields due to cool early season conditions, moisture stress before irrigation

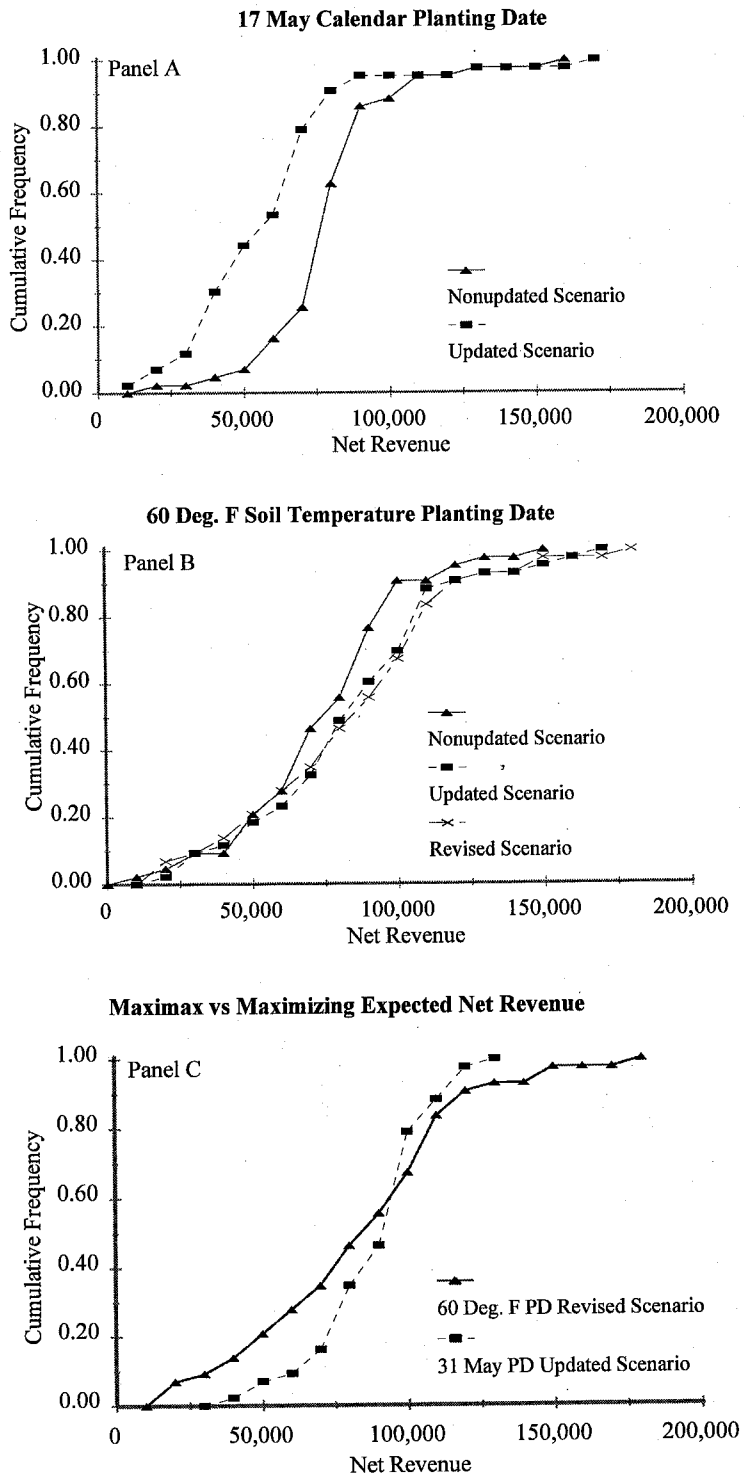


Figure 2. Net revenue for the maximax calendar and soil temperature planting date (PD) strategies

was available, and higher seeding rate and replanting costs. Decision makers with near risk neutral preferences are indifferent between the 31 May PD and the 60°F PD (table 3). Willingness to pay for soil temperature information when combined with soil moisture information at reproduction and revenue loss information at harvest was only positive for risk seeking decision makers. The risk premium that risk seeking decision makers are willing to pay rises by $3,398 from the updated scenario to $20,647. The 60°F PD appears to be consistent with observations by an extension cotton specialist who calls early planting followed by good growing conditions a "ring the bell" strategy (Banks). Farmers with the objective of "ringing the bell" plant early to take advantage of a longer growing season. When temperature and moisture conditions remain favorable, they "ring the bell" with a much higher net revenue than if the crop is planted later. However, the extent of this risk behavior by farmers in the irrigation district is unknown.

For the maximin decision criteria, increasing the seeding rate (100,000) and revising the soil moisture information (20% threshold of plant-available water) for the 31 May PD improved minimum net revenue to $39,501, virtually identical to the best calendar date irrigation strategy when updated with revenue loss at harvest information. The value of deviating from maximizing net revenue under extreme risk aversion does not improve with using soil moisture information to schedule irrigation.

Summary and Conclusions

Extension cotton specialists in southwest Oklahoma have been recommending planting a short-season cotton cultivar later in the growing season. The research here generally supports the recommendation. Biological and physical relationships that determine expected yields and net revenues were modeled using a cotton simulation model. Long-season, medium-season, and short-season cultivars were evaluated. Nonupdated, updated, and revised information scenarios were simulated to evaluate the impact of information about soil moisture at reproduction and yield and quality losses at harvest on cultivar and planting date decisions, as well as the distribution of net revenues.

In the analysis, factors that influenced cotton growth and development were cultivar choice, available growing season after planting, variability in the timing of reproduction due to the planting date selected, soil moisture information used to schedule irrigations, and the limited water allocation for irrigation. A farmer who maximizes net revenue would choose a late May calendar planting date, a short-season cultivar, and use soil moisture information to schedule irrigations at reproduction. The late May planting date is important for timing plant reproduction with available growing season and the late June availability of the irrigation allocation. Lower planting costs and better timing of reproduction with irrigation availability increased net revenue.

Risk neutral and risk seeking farmers would not be willing to pay for soil temperature information when combined with soil moisture information at reproduction and revenue loss information at harvest. Using soil temperature information to extend the growing season by planting early and using long-season cultivars (that have higher yield potential) increased risk and reduced mean net revenue. This result occurs due to increased planting costs, mistiming of reproduction with availability of limited irrigation water, and a growing season that is too short for longer maturing cultivars. However, the earliest soil temperature planting date criterion (60°F) when followed by soil moisture scheduled

irrigations produced the largest number of high net revenue values in the simulation. The 60°F planting date reduced mean net revenue by 6% compared with the maximizing net revenue strategy; however, the frequency of net revenue exceeding $100,000 is 33% compared with 21% for the maximizing expected net revenue strategy. The larger frequency of high net revenues may be enough to compensate for lower mean net revenue if farmers exhibit near risk neutral behavior and may explain why some farmers in the study area follow the riskier early planting strategy.

Several factors could change the results for planting dates based on the calendar versus soil temperatures. If producers receive a larger irrigation allocation, or vary the amount of water applied at each irrigation, mean net revenue could increase for the soil temperature planting date criterion. In the event of a wet planting season, waiting to plant in late May could significantly reduce net revenue by decreasing the number of acres the farmer could plant. Additional factors on which we had no data but which could alter the results include the adverse effects of chill stress on yield for the early planting date and the potential risk of greater insect damage with earlier planting dates.

[*Received March 1995; final version received September 1996.*]

References

Anderson, K. B., R. Sahs, and K. Felty. "Marketing Cotton Made Easy." In *Proceedings of the 1993 Beltwide Cotton Conferences,* pp. 456–58. Memphis TN: National Cotton Council of America, 1993.

Antle, J. M., and S. A. Hatchett. "Dynamic Input Decisions in Econometric Production Models." *Amer. J. Agr. Econ.* 68(November 1986):939–49.

Banks, J. C. State Extension Cotton Specialist, S.W. Agron. Complex Res. and Ext. Ctr., Altus OK. Personal communications, 1990.

Banks J. C., O. H. Williams, and N. B. Thomas. "Cotton: The Crop and Plant." In *Cotton Production and Pest Management in Oklahoma,* pp. 1–6. Circ. No. E-883, Coop. Ext. Serv., Oklahoma State University, 1992.

Bosch, D. J., and V. R. Eidman. "Valuing Information When Risk Preferences Are Nonneutral: An Application to Irrigation Scheduling." *Amer. J. Agr. Econ.* 69(August 1987):658–68.

Cochran, M. J., and R. Raskin. "A User's Guide to the Generalized Stochastic Dominance Program for the IBM PC Version GSD 2.1." Pub. No. SPO688, Dept. Agr. Econ. and Rural Soc., University of Arkansas, April 1988.

Goh, S., C. Shih, M. J. Cochran, and R. Raskin. "A Generalized Stochastic Dominance Program for the IBM PC." *S. J. Agr. Econ.* 21(December 1989):175–82.

Grube, A. H. "Participation in Farm Commodity Programs: A Stochastic Dominance Analysis: Comment." *Amer. J. Agr. Econ.* 68(February 1986):185–88.

Jackson, B. S., G. F. Arkin, and A. B. Hearn. "COTTAM: A Cotton Plant Simulation Model for an IBM PC Microcomputer." Pub. No. MP-1685, Tex. Agr. Exp. Sta., Texas A&M University, 1990.

King, R. P., D. W. Lybecker, A. Regmi, and S. M. Swinton. "Bioeconomic Models of Crop Production Systems: Design, Development, and Use." *Rev. Agr. Econ.* 15(May 1993):389–401.

Kirby, D. Manager, Lugert-Altus Irrigation District Office, Altus OK. Personal communications, 1990.

Larson, J. A., H. P. Mapp, L. M. Verhalen, and J. C. Banks. "Adapting a Cotton Model for Decision Analyses: A Yield-Response Evaluation." *Agr. Systems* 50(1996):145–67.

McCarl, B. A., and D. A. Bessler. "Estimating an Upper Bound on the Pratt Risk Aversion Coefficient When the Utility Function Is Unknown." *Aust. J. Agr. Econ.* 33(April 1989):56–63.

U. S. Department of Agriculture, Economic Research Service. *Cotton Situation and Outlook Report.* Pub. No. CWS-68, Washington DC, May 1992.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration. *Oklahoma Climatological Data.* Oklahoma State University Irrig. Res. Sta., Altus, Index No. 0179, Ashville, NC.

Verhalen, L. M., M. B. Bayles, and N. B. Thomas. "Cotton Varieties for Oklahoma: A Short Season Environment." In *Summary Proceedings Western Cotton Production Conference,* pp. 8–15, Oklahoma City OK, 13–14 August 1984.

Verhalen, L. M., and O. H. Williams. "Modifying Seeding Rates to Achieve a Stand of Cotton." In *Cotton Production and Pest Management in Oklahoma,* pp. 27–8. Circ. No. E-883, Coop. Ext. Serv., Oklahoma State University, 1992.

Waddle, B. A. "Crop Growing Practices." In *Cotton,* eds., R.J. Kohel and C.F. Lewis, pp. 233–63. Agronomy Monograph No. 24, Amer. Soc. Agron., Inc., Crop Sci. Amer., Inc., and Soil Sci. Soc. Amer., Inc., Madison WI, 1984.

Walker, O. L. Professor, Dept. Agr. Econ., Oklahoma State University, Southwest Representative Farm. Personal communications, 1990.

Walker, O. L., and D. D. Kletke. "Crop and Livestock Cost and Returns Budgets—Some Suggestions for Improvement." Pub. No. A.E. 9164, Dept. Agr. Econ., Oklahoma State University, September 1991.

Whisler, F. D., B. Acock, D. N. Baker, R. E. Fye, H. F. Hodges, J. R. Lambert, H. E. Lemmon, J. M. McKinion, and V. R. Reddy. "Crop Simulation Models in Agronomic Systems." *Advances in Agron*omy 40(1986): 141–208.

Williford, J. R. "Influence of Harvest Factors on Cotton Yield and Quality." *Transactions of the Amer. Soc. Agr. Eng.* 35(July–August 1992):1103–107.