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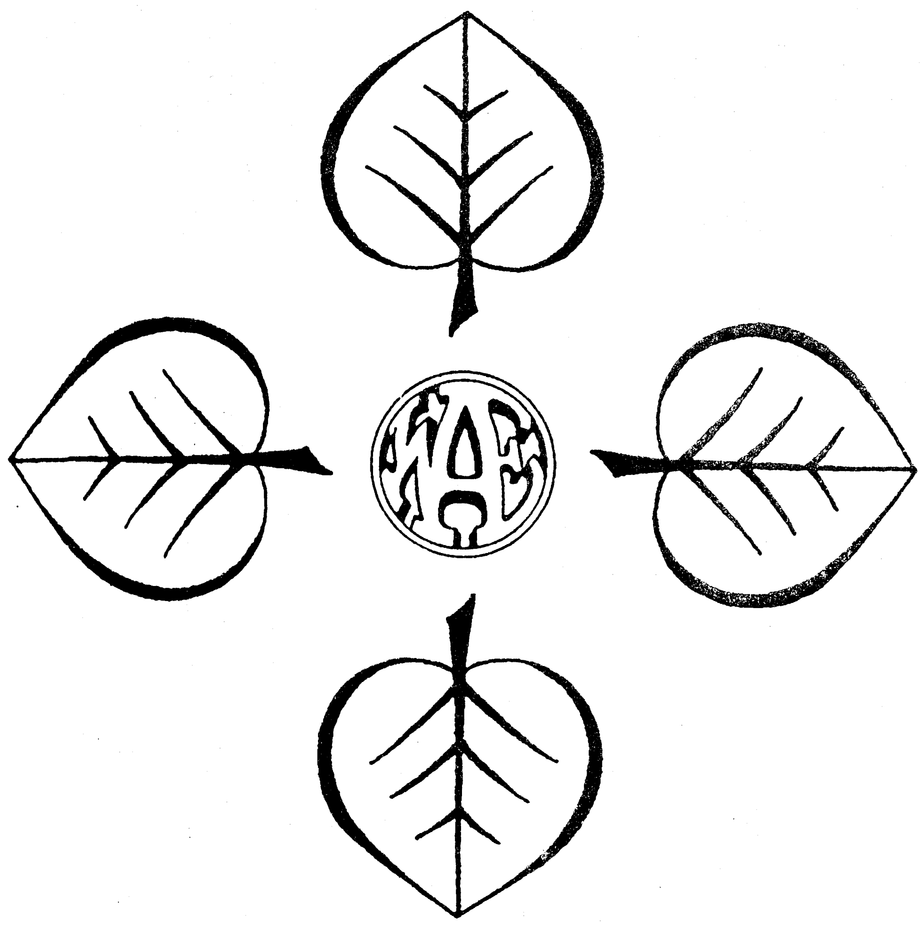

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WITH APOLOGIES TO SHAKESPEARE: TO PLANT OR NOT TO PLANT, THAT IS THE QUESTION

James A. Larson, Commodity Economics Division, Economic Research Service, U.S.D.A. and Harry P. Mapp, Regents Professor and Neustadt Distinguished Professor, Department of Agricultural Economics, Oklahoma State University.

ABSTRACT

Three parts of the cotton planting decision problem are examined: time of planting, seeding rate, and variety maturity length. Calendar date (open loop) and soil temperature determined (open loop with feedback) planting strategies are simulated using 1948-1990 weather data. Stochastic dominance and value of information criteria are used to evaluate net income.

The Oklahoma Rolling Plains is at the northern edge of the U.S. Cotton Belt. As a consequence, fewer day-degrees accumulate on average to fully exploit the yield potential of cotton. Of particular importance are volatile soil temperature and moisture conditions at planting time and during early growth. The first 30 to 40 days after planting determine cotton crop yield potential, after which it can only be maintained or lost (El-Zik and Frisbie). Adverse soil conditions decrease cotton stand survival and increase its susceptibility to early-season seedling disease complex and herbicide injury (Verhalen et al., 1984). Producers in southwest Oklahoma will on average plant 1.3 times and as many as five times in any given year in an attempt to get a viable plant stand (Banks). Consequently, the decisions of when to plant, the variety maturity length to plant, and the seeding rate substantially influence yield potential, planting variable costs, profitability, and risk for farmers in the Rolling Plains.

This paper examines the economics of this uncertain decision problem for irrigated cotton producers in southwest Oklahoma. Two planting decision rules are examined. The calendar date rule is an open loop or terminal action approach that uses a priori knowledge, i.e., information available before production begins. The soil temperature rule is an open loop with feedback or informational action approach (Antle; Hirshleifer and Riley). This latter rule uses a priori and current information about field conditions during germination and early growth.

RESEARCH METHODS

DECISION ALTERNATIVES

Three decisions are considered: when to plant, what variety maturity length to plant, and how much seed to plant. Farmers generally plant sometime between mid-April and mid-June. Their planting decision considers the tradeoff between the number of planting operations incurred due to unfavorable soil conditions for germination and growth and the yield potential or viability of the stand going into the reproductive stage.

Five calendar planting dates are specified for analysis: April 19, May 3, May 17, May 31, and June 14. Two-week intervals are chosen to represent the period after which the farmer must decide to replant due to adverse environmental conditions (Banks). These calendar dates are contrasted with three strategies based on a 10-day moving average of minimum soil temperatures. The temperature thresholds are 60°F, 65°F, or 70°F at the four inch depth. The basis for the soil temperature strategies is a study by Holekamp et al. which concludes farmers should use a 10-day average of minimum soil temperature at the four- to eight-inch depth to determine time of planting. Soil temperature is a forecast of satisfactory soil conditions occurring for germination and early growth. Producers also have three variety maturity length choices: long (Acala), medium (Delta), or short (Plains). Acala varieties have the greatest yield potential when day-degrees are not limited. However, earlier maturing varieties can outperform longer season varieties when day-degrees are limited.

The final part of the decision problem is the seeding rate. A harvest-time plant population of 50 to 60 thousand plants per acre for irrigated cotton is considered optimal (Banks). A population above this level can have a significant negative impact on yield. Five calendar date strategy seeding rates are specified: 60, 80, 100, 120, and 140 thousand seeds per acre. Five final target plant populations, which are determined by soil temperature, also specified: 40, 45, 50, 55, and 60 thousand plants per acre. A soil temperature-seedling survival relationship (Holekamp et al.) is used to determine seeding rate and a target plant population as functions of planting time soil temperature.

DEVELOPMENT OF SEED COTTON YIELD DISTRIBUTIONS

Per acre cotton lint and seed yield distributions for the planting alternatives are simulated using COTTAM, a daily time-step plant growth model (Jackson et al.). The COTTAM model is modified to account for the uncertainty of obtaining a plant stand in the Rolling Plains. The first uncertain field relationship is seedling emergence and survival. A field trial study of soil temperature-seedling survival (Holekamp et al.) is used to estimate the mean and variance of seedling survival proportion for each planting time using study area soil temperature data (U.S. Dept. Commerce). A truncated lognormal distribution is then used to generate random seedling survival proportions for each planting time i in year t for a 43-year period (1948-1990) using these means and variances,

(1) $$x_{it} = m_{it} + s_{it} \circ z_{it} \quad 0 \leq x_{it} \leq 0.60,$$

where m_{it} is average survival proportion, s_{it} is standard deviation of survival proportion, and z_{it} is a lognormally distributed random variate. Survival proportion is multiplied by seeding rate to determine plant population for planting time i in year t which is then incorporated into COTTAM.

Ideally, the emergence relationship in the cotton field should also be treated as a random variable that is correlated with soil temperature conditions, e.g., the binomial which would generate success or failure of stand emergence. Unfortunately, a literature search does not provide any data to specify the parameters of the binomial. The only guidance on emergence is an expert opinion that farmers have an average of 1.3 plantings and can plant as many as five times (Banks). Thus, an algorithm in COTTAM is used to determine time to emergence for planting time i in year t. Phase one of emergence is assumed to occur in one day for an average daily soil temperature at the planting depth of 78°F. Phase one development declines linearly to three days at 60°F. The second phase of emergence is determined using

(2) $$ENC = 0.0853 - 0.0057/(41.9 - ST) \bullet (ST - 34.44)^2 \circ WATCO,$$

where ENC is the hypocotyl elongation rate (centimeters/hour), ST is soil temperature, and WATCO is a water stress function. Emergence for planting time i in year t occurs when accumulated hypocotyl length is equal to seed planting depth (one inch). Elongation is delayed or declines when temperature is above 94°F or below 58°F. It is assumed that the stand will be replanted when time of emergence is greater than 14 days (Banks). These two procedures account for the direct and indirect consequences of soil temperature on plant population as a function of planting time.

Two cotton plant traits are significantly influenced by field population. Expected boll weight determines cotton plant carrying capacity. Boll weight data from a field study by Ray et al. is used to develop the linear equation,

(3) $$BSIZE_{it} = 6.39 - 0.00001412 \circ CRPOP_{it},$$

where $BSIZE_{it}$ is expected boll size for planting time i in year t and $CRPOP_{it}$ is plant population for plant date i in year t. Expected first main stem node fruiting branch number determines initiation of fruit production. It is a function of variety and plant population. In general, earlier varieties start fruiting site development on a lower main stem branch number than do later maturing varieties (Jackson et al.). Two assumptions are utilized to determine first fruit branch number. First, the average first fruit branch for each variety is assumed to be: short=5, medium=6, and long=7. Second, the mainstem node with a fruit branch is raised one node for each 11 plants per meter^2 increase in plant population (Buxton et al.). These two assumptions are used to define,

(4) $$EMSN_{it}^{short} = 4.64 + 0.000008517 \bullet CRPOP_{it},$$

(5) $$EMSN_{it}^{medium} = 5.64 + 0.000008517 \circ CRPOP_{it}, \text{ and}$$

(6) $$EMSN_{it}^{long} = 6.64 + 0.000008517 \bullet CRPOP_{it},$$

where $EMSN_{it}$ is expected first main stem node fruit branch number and $CRPOP_{it}$ is plant population for planting time i in year t. Both of these characteristics influence the planting time- and plant population-lint yield response relationships observed in the field (Verhalen, 1989 and 1990).

The COTTAM model, 1948-1990 daily weather data, and representative study area soil profile data are used to generate yields for the alternative planting strategies. Irrigation is restricted to 16 acre inches during the fruiting period because water is not available in the early growing season (Banks). Irrigation efficiency is assumed to be 60 percent. These assumptions are consistent with observed practices in the irrigation district used for this study. Additionally, it is assumed that insect damage is 15 percent, i.e., "good" insect management (Jackson et al.) and involves five spray operations for insect control (Walker and Banks).

NET FARM ENTERPRISE INCOME DETERMINATION

A representative southwest Oklahoma wheat/stocker and cotton farm is the basis for estimating net farm enterprise income: 288 acres of irrigated cotton with the other 872 acres devoted to wheat, dryland cotton, pasture, and setaside (Walker). Budget data developed by Walker and Banks for irrigated picker cotton are used to calculate net enterprise income. Income over variable costs to the 288 acre irrigated cotton enterprise is calculated for each initial planting date. Net farm enterprise incomes for the planting alternatives simulated reflect the costs of replanting when necessary.

STOCHASTIC DOMINANCE ANALYSIS

The value of each planting decision component is examined using a modified version of the Gould (1974) and Hess (1982) value of information definition and generalized stochastic dominance (GSD) (Bosch and Eidman; Mjelde and Cochran). Gould and Hess define information value as the difference in expected utility between an optimal act chosen under certainty and an optimal act chosen under uncertainty. The value of information definition for the analysis is the minimum (maximum) amount an individual within a specified class of agents would pay for the use of the perfect information (certainty) over the uncertain net enterprise income distribution. The three decision components--variety maturity length, seeding rate, and time of planting--are valued using this definition and GSD.

ANALYSES AND RESULTS

Average lint yields per acre for the calendar date strategies are: 856 pounds for the 25 short-season strategies, 779 pounds for the 25 medium-season strategies, and 695 pounds for the 25 long-season strategies. Irrigated field plot data are used to validate these lint yield results (Verhalen, 1989 and 1990). The modified COTTAM model accurately portrays: 1) lint yield levels and variability; 2) variety maturity-lint yield response, 3) lint yield as a concave function of planting time, 4) and lint yield as a function of stochastic plant population. The largest average number of planting operations occurs on the April 19th planting date (1.3). However, the model probably underestimates the total number of planting operations because the influence of excess rainfall events on the stand is not considered.

Five generalized stochastic dominance (GSD) criteria are used to identify utility maximizing planting strategies: 1) first-degree stochastic dominance ($r1 = -\infty$, $r2 = +\infty$); 2) risk neutral ($r1 = -0.000001$, $r2 = 0.000001$); 3) second-degree stochastic dominance ($r_1 = 0.00$, $r_2 = +\infty$); 4) moderately risk averse ($r_1 = 0.0001$, $r_2 = 0.0004$); 5) strongly risk averse ($r_1 = 0.0004$, $r_2 = 0.001$); and 6) risk preference ($r_1 = -0.0008$, $r_2 = -0.0001$) (Raskin and Cochran).

Thirteen of the calendar date strategies are in the first-degree stochastic dominance (FSD) efficient set (Table 1). All FSD strategies utilize the short-season (plains) variety. The two longer maturity choices are not in the FSD set. Exclusion of medium- and long-maturity strategies from the FSD set reflects a lack of day-degrees to fully utilize their yield potential. The FSD set clearly shows the influence of planting time, seeding rate, and stochastic plant population on the decision problem. The late planting time strategies (June 14th) are not in the FSD set because there is not enough growing season to take advantage of the yield potential of even a short maturity variety. Exclusion of the 140,000 seeding rate from the last two planting dates reflects the negative influence of excess population on yield. Further, the exclusion of the lower seeding rates at the first three planting dates indicates the impact of inadequate plant populations on yield.

Restricting the absolute risk aversion lower and upper bounds to risk neutral agents reduces the efficient set to one strategy: May 31 planting date using the 100,000 seeding rate (Table 1). It is the highest expected net enterprise income return among the 75 calendar date alternatives ($61,818). Limiting preferences to risk averse agents (SSD) produces an efficient set of three May 31 planting date strategies (Table 1). The SSD set includes the risk neutral and the two lowest seeding rate strategies (80,000 and 60,000). The May 31 planting date using the 80,000 seeding rate has an average net income which is $3,309 less than for the risk neutral strategy (Table 1). However, this strategy has a $4,491 higher minimum value than the 100,000 seeding rate strategy. The final member of the SSD set, which uses the 60,000 seeding rate, has only the tenth highest average net income among the 75 calendar date alternatives. However, this strategy has the highest minimum value among the 75 alternatives ($20,882). Narrowing preferences to slightly risk averse agents eliminates the 100,000 seeding rate from the risk averse set. The two remaining distributions are positively skewed and have the highest minimum values (Table 1).

GSD is used to estimate the premium needed to adopt one planting strategy over another (Raskin and Cochran). The least (most) that a slightly risk averse agent would need to adopt the highest average net return over the dominant 80,000 seeding rate strategy is $1,707 ($4,497), compared with $0.00 ($7,006) for the 60,000 seeding rate. Strongly risk averse agents prefer the 60,000 planting rate strategy from the SSD set. This strategy is the most positively skewed among the 75 alternatives and has the highest minimum value. The smallest (largest) premium needed for one agent in this class to adopt the risk neutral strategy over the dominant strategy is $7,006 ($7,370). Planting on May 17th using a 140,000 seeding rate is the preferred strategy for agents classified as risk seeking (Table 2). These agents appear to prefer the tradeoff of some expected return in exchange for the highest maximum net income value among the 75 alternatives ($129,248). Agents in this class would need a premium of between $1,825 and $26,532 to adopt the highest average return over the dominant strategy.

The calendar date strategy is based on a priori knowledge and is not influenced by the current field conditions (open loop decision rule). The next portion of the analysis examines the value of perfect variety choice, seeding rate, and time of planting information over the preferred base planting strategies. Then the use of a soil temperature planting rule is evaluated. This strategy considers current field condition information plus a priori knowledge. Decision maker willingness to pay (WTP) results indicate little value for variety choice, seeding rate, and time of planting information for agents classified as risk preferring (Table 2). Perfect information about the decision problem does not produce a more desirable distribution of net income for this class of agents. The valuation results are more mixed for the slight risk aversion and risk neutral cases. There is no WTP for variety choice information for both classes of decision makers. However, the value of perfect information about seeding rate ranges from $1.25 per acre to $7.64 per acre on the lower absolute risk aversion bound. There is value for additional time of planting information only for the risk neutral case ($23.31 per acre on the lower bound).

The final part of the analysis examines a soil temperature predictor to determine time of planting and seeding rate assuming the use of a short-maturity variety. Soil temperature is a predictor of field conditions for early plant growth. However, as with the calendar date strategy, it is an imperfect predictor of field conditions for early plant growth. The crop is assumed to be planted when the minimum daily soil temperature achieves a specified threshold, 60°F, 65°F, or 70°F, for ten consecutive days. Average lint yields vary from 875 to 936 pounds per acre. The highest average lint yield strategy is the 65°F-55,000 target population rule (936 pounds per acre). The highest expected net income strategy is the 65°F-50,000 target population rule ($55,678). The highest minimum net income strategy is the 65°F-45,000 target population rule ($12,489). On the other hand, the highest maximum return soil temperature rule is the 60°F-50,000 target population strategy. In general, the 65°F rule results in the highest average and minimum net enterprise income. This result is consistent with the average soil temperature at planting time of 64°F in the perfect information set. However, none of the soil temperature rules dominates the four preferred calendar planting date strategies. The use of a soil temperature rule over a calendar date planting rule does not result in a more desirable net income distribution. The premiums needed to adopt the highest expected net income soil temperature rule over the preferred calendar date rule are presented in Table 2. These premiums represent the amount needed to make a class of agents indifferent between the two rules. They also represent the minimum improvement in income from the timed decision rule before it would be preferred.

CONCLUSIONS

Three parts of the cotton planting decision problem are examined under Oklahoma Rolling Plains conditions: time of planting, seeding rate, and variety maturity length. The COTTAM simulation model is modified to generate yield distributions for a representative farm with 288 acres of irrigated cotton. Calendar date (open loop) and soil temperature determined (open loop with feedback) planting strategies are simulated using 1948-1990 daily weather data. Stochastic dominance and value of information criteria are used to evaluate net income.

Calendar date planting strategies dominate soil temperature planting rules under Oklahoma conditions. Four risk efficient strategies are identified. Each employs the short maturity cotton variety. Risk neutral and risk averse agents prefer the late May planting. Risk seekers prefer the mid-May planting. Seeding rate varies according to risk preference. The analysis indicates that the soil temperature planting rules do not dominant the preferred calendar strategies. Current stage information in the form of an imperfect predictor (soil temperature) does not result in a more desirable net enterprise income distribution for the risk neutral, risk averse and risk preferring classes of decision makers examined in this study. Thus, under Oklahoma growing conditions the calendar date (open loop) planting rule dominates the soil temperature (open loop with feed back) planting strategy.

TABLE 1. RISK EFFICIENT CALENDAR PLANTING DATE STRATEGY SET RESULTS

Risk Efficient Calendar Date Strategy Efficient Sets[a]

Planting Date	Planting Rate Per Acre: 60,000	80,000	100,000	120,000	140,000
April 19th				A1	A1
May 3rd			A1	A1	A1
May 17th		A1	A1	A1	A1F1
May 31st	A1C1D1E1	A1C1D1	A1B1C1	A1	
June 14th					

Statistics of the Risk Efficient Sets

Planting Date (Mo./Day)	Strategy Variety Maturity	Seeds/ Acre (000's)	Pounds of Lint Per Acre/Dollars of Net Income: Average	Standard Deviation	Maximum Value	Minimum Value	Skewness
5/31	Short	60	869	116	1,284	648	1.07
			$49,575	$14,828	$101,563	$20,882	0.98
5/17	Short	80	883	157	1,381	572	0.72
			$50,684	$20,209	$113,574	$10,202	0.71
5/31	Short	80	944	116	1,312	632	0.55
			$58,509	$14,854	$104,432	$18,002	0.45
5/03	Short	100	880	200	1,370	427	-0.31
			$48,920	$25,606	$111,544	$9,562	-0.28
5/17	Short	100	941	156	1,461	540	0.62
			$57,417	$20,069	$123,007	$5,123	0.56
5/31	Short	100	975	126	1,305	604	-0.10
			$61,818	$16,217	$102,716	$13,511	-0.20
4/19	Short	120	881	208	1,278	448	-0.34
			$46,866	$27,411	$100,136	$8,302	-0.25
5/03	Short	120	902	206	1,453	424	-0.14
			$51,174	$26,618	$121,320	$10,656	-0.13
5/17	Short	120	959	163	1,508	496	0.47
			$58,954	$21,072	$128,259	$1,344	0.40
5/31	Short	120	968	132	1,264	569	-0.37
			$60,079	$17,031	$96,692	$8,205	-0.45
4/19	Short	140	909	206	1,274	456	-0.4
			$49,336	$27,454	$99,702	$7,456	-0.33
5/03	Short	140	901	209	1,465	422	-0.05
			$49,971	$27,090	$122,209	$11,596	0.00
5/17	Short	140	947	169	1,521	456	0.35
			$56,623	$21,962	$129,248	$7,403	0.27

[a] Risk efficiency criteria are represented in the top section of the table by: A=first-degree stochastic dominant set; B=risk neutral set; C=second-degree stochastic dominance set; D=moderately risk averse set; E=strongly risk averse set; and F=risk preference set. Variety maturity length is represented in the top section of the table by: 1=short; 2=medium; and 3=long.

TABLE 2. ECONOMIC ANALYSIS VALUATION RESULTS

DECISION MAKER WILLINGNESS TO PAY (WTP) FOR PERFECT VARIETY CHOICE, SEEDING RATE AND TIME OF PLANTING INFORMATION

	Preferred Calendar Strategy:			WTP for Additional Information on:		
Efficiency Criteria	Variety Maturity Length	Planting Date Mo/Day	Seeding Rate/ Acre	Variety Choice	Seeding Rate (Dollars/Acre)	Time of Planting
Risk Preference	Short	5/17	140,000			
Lower Bound				$0.00	$0.00	$0.00
Upper Bound				0.42	$1.63	$4.19
Risk Neutral	Short	5/31	100,000			
Lower Bound				$0.00	$5.17	$23.31
Upper Bound				$0.00	$6.00	$29.69
Risk Aversion						
Slight	Short	5/31	80,000			
Lower Bound				0.00	$7.64	0.00
Upper Bound				$0.00	$10.58	$8.80
Slight	Short	5/31	60,000			
Lower Bound				$0.00	$1.25	$0.00
Upper Bound				$0.00	$31.42	$8.80
Strong	Short	5/31	60,000			
Lower Bound				$0.00	$0.01	$0.00
Upper Bound				$0.00	$1.25	$0.00

PREMIUM TO ADOPT 65°F SOIL TEMPERATURE/50,000 TARGET PLANT POPULATION DECISION RULE OVER THE PREFERRED CALENDAR PLANTING STRATEGY:

Efficiency Criteria	Variety Maturity	Planting Date Mo/Day	Seeding Rate/ Acre	Dollars/ Acre
Risk Preference	Short	5/17	140,000	
Lower Bound				21.26
Upper bound				24.08
Risk Neutral	Short	5/31	100,000	
Lower Bound				16.26
Upper Bound				26.23
Risk Aversion				
Slight	Short	5/31	80,000	
Lower Bound				28.92
Upper Bound				43.80
Slight	Short	5/31	60,000	
Lower Bound				32.05
Upper Bound				57.59
Strong	Short	5/31	60,000	
Lower Bound				38.01
Upper Bound				40.89

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