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POTENTIAL ECONOMIC BENEFITS OF ADJUSTING COTTON DRYLAND PRACTICES BASED ON SEASONAL RAINFALL EXPECTATIONS

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Abstract

Cotton (*Gossypium hirsutum* L.) is a major rainfed field crop grown in the semiarid regions of the Texas High Plains. Frequent droughts along with high climatic variability account for the low cotton yields obtained in this region. Cropping practices that might be used to take advantage of seasonal rainfall conditions include crop choice, planting density, planting date and fertilization practices. At present very little or no information is available to encourage High Plains dryland cotton farmers to modify cropping practices to take advantage of weather information in good years or reduce losses in poor years. CroPMan simulation model was used to evaluate the economic benefits of using alternative management practices for dryland cotton. The potential economic benefits of tailoring dryland cotton production practices to seasonal rainfall expectations was found to be from \$17 to \$21 million per year for the Texas High Plains. Results from this study reveal that dryland cotton farmers could benefit from modifying cropping practices based on seasonal rainfall expectations.

Introduction

Climate variability in terms of temperature or precipitation anomalies brings uncertainty to agriculture and often results in decreased revenues through lost production. El Niño/ Southern Oscillation (ENSO) phenomenon is considered to be the main source for interannual climate variability in many parts of the world (Baethgen, 1998). ENSO brings changes in sea surface temperatures and creates unusual weather events like excessively wet or hot dry conditions on earth surface. As a consequence, positive rainfall anomalies prevail in El Niño years, and negative rainfall anomalies exist in La Niña years. For general understanding on ENSO mechanism and its effects, the readers are encouraged to refer the works of McCreary and Anderson (1991), and Cane (2000). The influence of ENSO phenomenon on crop yields and the subsequent economic impact on US farmers is well documented in the economic literature (Chen et al., 2002; Jochec et al., 2001; Mjelde and Penson, 2000; Jones et al., 2000; Hill et al., 2000,1999; Solow et al., 1998; and Mjelde et al., 1997).

Progress in understanding the ocean atmosphere interactions and technological advances played a vital role in making seasonal (3 month) climate forecasts a reality (Hunt and Hirst 2000; and Nicholls et al., 2000). *Seasonal Climate Outlook* from Climate Prediction Center and International Research Institute for Climate Prediction regularly offers updates and discussion on seasonal forecast information. Climate information of expected seasonal rainfall (normal, below or above normal rainfall season) can help in managing intraseasonal crop management and reduces the vulnerability to climate risks (Russel, 1991). If the forecast for the next season reveal a possible drought, then the best possible way to reduce losses is to decrease an input use and increase the cost savings. Thus, climate information can support farmers in reducing risk by allowing them to alter their production strategies by taking advantage of opportunities in good years and reduce losses in poor years (Arthur, 2001). Realizing these opportunities, however, is not straightforward and thorough examination of dryland cropping practices need to be analyzed for assessing potential economic benefits. Hence the objectives of this paper are to (i) select the appropriate cotton management practices (planting dates, plant densities and fertilization quantities) that can enhance the profitability/reduce losses under conditions of climate change, and (ii) identify the potential value of adjusting management of High Plains cotton to seasonal rainfall expectations

Study Area Importance

Dryland agriculture is a major enterprise for the High Plains of Texas. The Texas High Plains is classified as a semiarid area with an annual rainfall of 450 mm and evapotranspiration ratio of less than 0.25. The uncertainty related with weather variability is a big challenge for farmers and millions of dollars are lost annually in this region due to temperature and moisture stress effects (Middleton et al., 1996). Droughts lasting six months occur more frequently in West Texas, while longer droughts are found most often in the Northern part of Texas (TWRI). Out of 18.48 million acres of land devoted to field crops in Texas, twelve million acres are rainfed. Of these 12 million acres, 4.8 million acres are located in the High Plains of Texas. Cotton is one of the primary dryland crops in this area with an average yield of 260 pounds/acre. This yield level represents less than half of its irrigated counterpart yield of 653 pounds/acre (TASS, 2001). Hockley County, the largest dryland cotton-producing county in 2001 for the Texas High Plains area was purposefully selected for analyzing the potential economic benefits of adjusting cotton management practices to seasonal rainfall expectations.

Methods

Model Simulation

As conventional field experimentation is costly and time consuming, consequently, crop simulation models are gaining importance as valid alternatives. Crop simulation models allow the evaluation of one or more options that are available with respect to one or more management decisions (Tsuji et al., 1998). Further, simulation modeling is efficient as timeframes of many years can be simulated quickly and inexpensively for many areas and for unlimited management strategies (USDA-ARS, 1993). Simulation modeling can be described as a technology used to construct a substitute for growing a crop in reality, and can be analyzed or manipulated with far greater ease than the complex and cumbersome real crop (SivaKumar and Glinni, 2002). Various researchers have used crop simulation models in conjunction with historical climate data to determine the effects of management practices on the yield of field crops. The examples include, sorghum (Carberry et al., 2000; McCown et al., 1996; Hammer and Muchow, 1994), wheat (Meinke et al., 1998; Meinke and Stone, 1997; McCown et al., 1996; Hammer et al., 1987), and cotton (Carberry et al., 2000; Hammer, 2000).

CroPMan version 3.1 (Crop Production and Management Model), as developed at the Blackland Research and Extension Center, Texas Agricultural Experiment Station, Temple, Texas was used in the present study to simulate crop yields. CroPMan is a computer framework designed to simulate production and assist growers in identifying the best management practices that can enhance the profitability. The Environmental Policy-Integrated Climate – EPIC for short, (Williams et al., 1983) is the engine of CroPMan. Management practices that can be simulated using CroPMan include but not limited to planting date, crop maturity, plant population, crop type and rotation sequence. The CroPMan database program includes actual soils and weather station data for the twelve Extension Districts in Texas. CroPMan uses actual daily weather data from established weather stations and statistically simulates random weather patterns for future season crop yields. Periods of drought, intense and abnormal rainfall are all simulated based on their past occurrence.

CroPMan Model Validation

Before applying the model to the present investigation, proper validation of CroPMan is required. The objective of validation was to see if the simulated results agreed with the actual observed yields. Validation can be defined as "comparison of the predictions of a verified model with experimental observations other than those used to build and calibrate it, and identification and correction of errors in the model until it is suitable for an intended purpose" (Whisler et al., 1986). Validation provides continuous evaluation of a simulation model through feedback information from researchers, and also from farmers and farm managers who operate in variable climate and soil conditions (Reddy et al., 2002). Examples of simulated yield validations for different crops for the Texas High Plains and the central Texas areas can be found in the works of Gray et al. (1997), Chen et al. (2000), and Harman et al. (2004).

Annual dryland cotton yields for 1991 to 2000 period was used in this study to calibrate crop parameters in CroPMan. The annual dryland cotton yield values were collected from the National Agricultural Statistics Service (NASS) database and the values were compared with the simulated CroPMan yields for the same period. CroPMan model was validated for the first three largest cotton-producing counties in 2001 (Hockley, Lynn and Floyd) for the Texas High Plains (TASS). The relative error E_i for each calibration was calculated (Mizina et al., 1996) as follows:

$$E_i = |(Y_{act} - Y_{sim})/ Y_{act}|*100,$$

where E_i = Relative error, Y_{act} = Actual crop yield, and Y_{sim} = Simulated crop yield

The CroPMan validation results are presented in Table 1. The bias in yields reported by CroPMan for dryland cotton was found to be in the range of 0.99 to 4%. Overall, the validation results show that CroPMan performed effectively for cotton across different counties.

Simulation Model Specifications

Cropping practices that might be used to take advantage of seasonal rainfall conditions would include crop choice, planting density, planting date and fertilization quantities. A typical dryland cotton calendar of practices recommended for the High Plains is shown in Table 2. The suitable planting and harvesting dates for the High Plains were identified using the Texas commodity calendar of the Texas A&M University system. Effects of planting dates were tested in weekly intervals ranging from May 1 to June 28, and planting densities were tested in 1000 plants/acre increments from 30,469 plants/acre to 45,469 plants/acre. Impacts of elemental nitrogen and fertilizer blends of 22-08-02, and 28-11-04 on dryland cotton profitability were also studied. The fertilizer blends were increased at an interval 25 pounds/acre from 75 lbs/acre to 300 lbs/acre where as elemental N was increased at 10 pounds interval from 0 lbs/acre to 60 lbs/acre. The prices for fertilizer blends were calculated manually based on nutrient grade.

Capturing Climatic Variability With CroPMan

A combined effort was made in simulating the effects of variable climatic conditions on dryland cotton production in the Texas High Plains, in which the actual meteorological data was integrated with the CroPMan software. The weather input file (*.dly) in CroPMan utilizes the daily weather values from 1956 to 2000. These data include daily values for precipitation (mm), maximum and minimum temperatures (ºC), solar radiation (MJ/m^2), relative humidity (%), and wind speed (m/s). The Levelland weather station database (Hockley County) of the National Weather Service represented as the baseline scenario. Actual precipitation data for Hockley County from 1991 to 2000 cotton growing season was collected, and the maximum and minimum amounts were identified. Levelland weather station database values were increased/decreased proportionately to the observed maximum and minimum rainfall levels to reflect the effects of climate change. The assumption made for this scenario was, the minimum rainfall level represents the driest climate (below normal) and the maximum rainfall represents the wettest climate (above normal scenario). Under these changed weather scenarios, CroPMan simulations were ran for different management practices (planting date, plant population and fertilization etc.,) to obtain the simulated yield.

Decision Making Under Uncertainty

This study used stochastic dominance with respect to a function (SDRF) to select the best combination of crop management strategies for producers with different risk preferences. SDRF is more flexible than other stochastic dominance approaches, such as first degree and second degree because SDRF allows precise valuation of the choices for the selected lower and upper bounds of the absolute risk aversion coefficient. SDRF does not impose global restrictions on decision maker's utility functions and can be used to model a wider spectrum of risk attitudes than either E-V analysis or second-degree stochastic dominance (SSD) via the Arrow-Pratt risk aversion coefficient (Giesler et al., 1993). Mathematically, the Arrow-Pratt risk aversion coefficient (r_x) is defined as $-U''(x)/U'(x)$, where U represents the decision maker's utility function and x is income or wealth and $U''(x)$ and $U'(x)$ are the first and second derivatives of the Von Neumann-Morgenstern utility function with respect to net returns. With SDRF, classes of utility function can be established by using risk preference intervals bounded by a lower risk aversion coefficient $r_1(x)$ and a upper risk aversion coefficient $r_2(x)$ which characterize the general degree of risk aversion for managers (Williams, 1988).

Stochastic dominance with respect to a function analysis was conducted using Simetar (Simulation for Applied Risk Management), a Microsoft Excel Add-In program developed by Richardson (2002). For practical purposes, three alternative risk intervals for the dryland cropping systems of the Texas High Plains in the range –0.0003 to 0.0006 (risk neutral -0.0003 to 0.001; slightly risk averse 0.00 to 0.0003; strongly risk averse 0.0003 to 0.0006), similar to those used by Segarra et al., 1991; and Bennett et al., 1997 were used in the present study. Average variable costs for dryland cotton were based on Texas Cooperative Extension budgets, 1998-2003 (Table 3). By multiplying the simulated yields by the appropriate price ($0.55 per pound of cotton lint), the expected gross revenues were derived. Net returns per acre were obtained by subtracting the variable costs from gross revenues. The simulated data was used to investigate different management strategies in order to derive stochastically efficient management practices.

Results and Discussion

Adaptation of Management Practices

A total of 124 different simulated yields were generated under the alternative dryland cotton production practices (based on all combinations of sixteen planting densities, ten planting dates, three fertilizer types, three fertilizer levels, twenty seven best management combinations, and two rainfall scenarios). Cotton yield levels at Hockley County ranged from 214.22 lb lint/acre to 318.9 lb lint/acre across all planting densities and weather conditions. It was found that rainfall changes had a significant effect on cotton yields. Population density of 35,469 plants/acre (Table 4) resulted in higher returns at Hockley County for below normal rainfall conditions. Under conditions of good rainfall, higher returns were achieved with higher plant populations. Accordingly 39,469 plants/acre would be recommended for higher profits for Hockley County (Table 5). However, comparing the "SDRF ranking" of plant densities to those obtained under "average net return ranking" approach (Tables 4 and 5), it can be evident that the rankings were different. Under SDRF approach, planting densities of 32,469 and 40,469 plants/acre are the preferred choices under below and above rainfall conditions, respectively. Cotton producers not only concerned with the "average" performance of their practices, but also take into consideration of inherent variability of dryland production systems. For this reason, SDRF ranking was considered superior to average net return ranking approach.

Cotton in the Texas High Plains is generally grown under erratic and limited rainfall conditions. Having an optimum planting density assures dryland farmers a proper crop establishment even under adverse weather conditions. Current recommendations of cotton planting density under dryland conditions of the Texas High Plains ranged from 30,000 plants/acre to 75,000 plants/acre. These planting density recommendations are based on the type of row spacing being used (conventional: 40 inch, narrow: 30 inch, and ultra narrow row (UNR): below 20-inch spacing) and the cotton plant's ability to react to varied climatic and soil moisture conditions. The present analysis is conducted to further reduce this pane and aimed to provide a narrow planting recommendation suitable for changing climatic conditions of the Texas High Plains. The present study's recommended population levels (32,469 and 40,469 plants/acre under below and above normal rainfall conditions, respectively) are low when compared to 15-inch row: 50,000 plants/acre as recommended by Prince et al., 1999 for dryland cotton in south Texas.

Cotton is generally planted in the months of May to June in the Texas High Plains. Under conditions of below normal rainfall, the response of cotton to different planting dates ranged from 124.15 lb lint/acre to 221.52 lb lint/acre (Table 6). Cotton responded favorably to rainfall and the yields in good rainfall situations ranged from 180.14 lb lint/acre to 318.90 lb lint/acre (Table 7). Net returns were significantly lower for late June cotton plantings when compared with returns in the early and late May plantings. The SDRF results showed that early planting is advisable under above normal rainfall conditions, thus the first week of May was found to be the optimal planting date for cotton for Hockley County. If the coming season is expected to be a below normal one, plantings could be delayed till mid May.

Planting around the 1st of May under good rainfall conditions permits rapid germination and the cotton plant attains its bloom period in time for the normal summer showers, which are likely to occur in late June and July. If planting were delayed till the end of June, the cotton yields would be reduced by 44% in Hockley County irrespective of rainfall situations. Similarly, Hale (1936) reported a 50% reduction in cotton yield with delayed planting, whereas Porter et al. (1996) reported more than 25% decrease in lint yields if cotton planting was delayed until June. The simulated results showed that the CroPMan model was able to simulate the yield decline due to delay in the planting dates.

The effect of fertilization practices revealed that, at below normal rainfall conditions, 10 lb of elemental N or 75 lb of 22-08-02, or 100 lbs of 28-11-04 fertilizer blends would be needed for a stress free plant growth (Table 8). Among all the three fertilizer types, it was found that the returns would be higher with 75 lbs of 22-08-02 fertilizer under below normal rainfall conditions. Only elemental N was responded under conditions of higher rainfall, and accordingly 20 lbs of elemental N was required (Table 9). Howard and Gwathmey (1998) echoed similar finding, suggesting higher nitrogen rates in case of excessive rainfall. The effect of fertilizer blends remained the same at both below and above rainfall scenario levels. Also under both rainfall scenarios, the average net return rankings and the SDRF rankings were found to be the same.

Generally, cotton requires little N fertilizer and therefore has little nitrogen reponsivity under non-irrigated conditions since the selected Arch fine sandy loam soils (0 to 2% slope) in Hockley County had sufficient organic N to mineralize and keep up with plant needs. Cotton response for fertilization is more evident under irrigated conditions where yields and plant requirements are higher. Thus, for efficient crop fertilization decisions, farmers should take into consideration of soil fertility levels of a given field, stage of crop growth and crop specific nutrient needs.

Best Combination of Management Practices

The top three risk efficient management practices with respect to planting density, planting date and fertilization are combined with other practices and the yield levels were simulated using CroPMan to evaluate the economic benefits of seasonal rainfall information. Cotton management combination results for Hockely County for below normal rainfall conditions are presented in Table 10. The results indicate that initiating planting on 1st May with a population density of 36,469 plants/acre and using 75 lbs of 22-08-02 fertilizer would maximize the profits. The corresponding profit at these combinations is –$86.12/acre. If the planting is delayed by a week or two due to unfavorable climatic conditions, then the next best planting strategy will be planting on 7th or 14th May with plant population of 35,469 plants/acre and 75 lbs of 22-08-02. The economic analysis reveal that modifying cotton practices under below normal rainfall conditions would save a Hockley dryland cotton farmer up to $12.09/acre as against adopting the normal recommended management practices.

If the coming season is forecasted as an above average season, then the recommended strategy to follow for Hockley County is to initiate planting on 1st May with a planting density of 44,469 plants/acre and using 75 lbs of 22-08-02 fertilizer (Table 11). Following these combinations, a dryland cotton farmer in Hockley County could achieve a profit of –$34.72/acre. Under conditions of delayed planting, the best way to decrease losses would be using a planting density of 35,469 plants/acre while maintaining the same fertilizer levels. Similarly increasing the fertilizer up to 125 lbs/acre while maintaining the planting density at 35,469 plants/acre would reduce the negative impacts of late planting till 14th May by realizing the profits up to –$35.25/acre. When compared against costs involved under normal recommended production practices (Table), adjusting cotton management practices under above normal rainfall conditions would benefit Hockley dryland cotton producers up to $9.93/acre, respectively.

Total dryland cotton planted in the Texas High Plains is about 1.7 million acres in 2001. If a dryland farmer uses seasonal climate information to modify crop management practices, then the expected potential savings in farm income for the Texas High Plains area alone is anywhere from $17 to $21 million per year. Even though, estimating economic benefits of climate information depend on many factors, results reported in this study provides a rough estimate of magnitude of benefits associated with climatic information.

Conclusions

Given the semiarid climate and unpredictable weather conditions of the Texas High Plains, farmers in this area often experience substantial decreases in dryland crop yields when compared relative to the yields of irrigated crops. The best possible way to reduce the negative impacts of climatic variability is to find suitable production management practices that consider the most likely environmental conditions expected for the next growing season. CroPMan simulated results for two rainfall scenarios (below and above normal) showed that dryland farmers in the Texas High Plains area would clearly benefit from adjusting crop management practices based on expected seasonal rainfall information. The potential savings in farm income for the region would be anywhere from $17 to $21 million per year.

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Table 1. CroPMan model validation results for cotton in the Texas High Plains.

County	Actual Yield (lbs/acre)	Simulated Yield (lbs/acre)	Percent of Error
Hockley	296.5	284.8	3.9
	(87.92)	(100.4)	
Lynn	315	318.9	1.2
	(101.7)	(142.18)	
Floyd	331.7	328.4	0.99
	(115.0)	(115.6)	

* Figures in the parentheses indicate standard deviation.

Table 2. Calendar of dryland cotton practices in the Texas High Plains.

Type of Operation	Operation	Day	Type Applied	Rate	Maturity Days
Plow/cultivate/other	Plow, Chisel 20 feet	02/01			
Pesticide	Chemical application	03/01	Treflan 4.00 EC	0.19 gal/acre	
Plow/cultivate/other	Plow, Chisel 20 feet	03/10			
Fertilize	Fertilizer application	04/25	28-11-04	214.25 lbs/acre	
Plow/cultivate/other	Plow, Chisel 20 feet	05/01			
Pesticide	Chemical application	05/17	Temik 15G 45lb	4.00 lb/acre	
Plant	Planter, 8 Row	05/17		40,469 plants/acre	161
Plow/cultivate/other	Plow, Chisel 20 feet	06/01			
Pesticide	Chemical application	06/20	Di Syston 8	0.25 gal/acre	
Plow/cultivate/other	Plow, Chisel 20 feet	07/01			
Pesticide	Chemical application	07/01	Methyl Parathion 4 EC	0.06 gal/acre	
Pesticide	Chemical application	07/01	Asana XL	0.01 gal/acre	
Pesticide	Chemical application	07/15	Methyl Parathion 4 EC	0.06 gal/acre	
Plow/cultivate/other	Plow, Chisel 20 feet	07/15			
Pesticide	Chemical application	07/15	Asana XL	0.01 gal/acre	
Pesticide	Chemical application	08/10	Asana XL	0.01 gal/acre	
Pesticide	Chemical application	08/10	Methyl Parathion 4 EC	0.06 gal/acre	
Harvest	Stripper	10/10			

Table 3. Example of a dryland cotton budget, Hockley County, Texas.

Cotton, Dryland (skip-row), 2003 projected costs and returns per ground acre.				
Total income	**Quantity**	**Units**	**$/Unit**	**Total ($)**
Cotton lint	254	lb	0.55	139.70
Cotton seed	0.2	ton	100.83	20.16
				159.86
Variable costs				
Fertilizer and application	1.0	acre	11.93	14.98
Insecticide and application	3.0	acre	8.03	24.09
Herbicide costs	1.0	acre	12.50	18.04
Seed	18.0	lb	0.60	10.80
Fuel				14.39
Repairs				20.98
Labor	3.85	hr	8.00	30.80
Crop insurance	0.66	acre	15.00	9.90
Miscellaneous			13.45	13.45
Harvest				
Gin, bags, ties, and marketing				37.39
Stripping				15.21
Interest on operating capital				8.68
Total variable costs				218.71
Returns to management				-58.85

*Texas cooperative extension budgets.

Table 4. Effects of plant population under below normal rainfall scenario.

Population Plants/acre	Yield lb	Gross Returns $/acre	Variable Cost $/acre	Profits $/acre	Avg. Net Return Ranking	SDRF Ranking
30,469	214.22	117.82	215.69	-97.86	10	10
31,469	214.22	117.82	215.99	-98.17	13	13
32,469	216.65	119.15	216.29	-97.13	3	1
33,469	216.65	119.15	216.59	-97.44	4	4
34,469	216.65	119.15	216.89	-97.74	8	8
35,469	219.09	120.49	217.19	-96.69	1	2
36,469	219.09	120.49	217.50	-97.00	2	3
37,469	219.09	120.49	217.80	-97.50	6	6
38,469	219.09	120.49	218.10	-97.60	7	7
39,469	219.09	120.49	218.40	-97.90	11	11
40,469	219.09	120.49	218.71	-98.21	14	14
41,469	219.09	120.49	219.00	-98.50	16	15
42,469	221.52	121.83	219.30	-97.47	5	5
43,469	221.52	121.83	219.61	-97.77	9	9
44,469	221.52	121.83	219.91	-98.07	12	12
45,469	221.52	121.83	220.21	-98.38	15	16

Table 5. Effects of plant population under above normal scenario.

Population Plants/acre	Yield lb	Gross Returns $/acre	Variable Cost $/acre	Profits $/acre	Avg. Net Return Ranking	SDRF Ranking
30,469	309.16	170.03	215.69	-45.65	15	15
31,469	309.16	170.03	215.99	-45.95	16	16
32,469	311.59	171.37	216.29	-44.91	7	7
33,469	311.59	171.37	216.59	-45.22	10	9
34,469	311.59	171.37	216.89	-45.52	13	13
35,469	314.03	172.71	217.19	-44.48	2	2
36,469	314.03	172.71	217.50	-44.78	5	5
37,469	314.03	172.71	217.80	-45.08	9	10
38,469	314.03	172.71	218.10	-45.38	12	12
39,469	316.46	174.05	218.40	-44.35	1	4
40,469	316.46	174.05	218.71	-44.65	4	1
41,469	316.46	174.05	219.00	-44.95	8	8
42,469	316.46	174.05	219.30	-45.25	11	11
43,469	316.46	174.05	219.61	-45.55	14	14
44,469	318.90	175.39	219.91	-44.51	3	3
45,469	318.90	175.39	220.21	-44.82	6	6

Table 6. Planting date influences under below normal rainfall scenario.

Planting Date	Yield lb	Gross Returns $/acre	Variable Cost $/acre	Profits $/acre	Avg. Net Return Ranking	SDRF Ranking
05/01	221.52	121.83	218.71	-96.87	1	3
05/07	221.52	121.83	218.71	-96.87	1	2
05/14	221.52	121.83	218.71	-96.87	1	1
05/21	221.52	121.83	218.71	-96.87	1	4
05/28	214.22	117.82	218.71	-100.88	2	5
06/01	209.35	115.14	218.71	-103.56	3	6
06/07	192.31	105.77	218.71	-112.94	4	7
06/14	182.57	100.41	218.71	-118.29	5	8
06/21	155.80	85.69	218.71	-133.02	6	9
06/28	124.15	68.28	218.71	-150.42	7	10

Table 7. Planting date influences under above normal rainfall scenario.

Planting Date	Yield lb	Gross Returns $/acre	Variable Cost $/acre	Profits $/acre	Avg. Net Return Ranking	SDRF Ranking
05/01	318.90	175.39	218.71	-43.31	1	1
05/07	316.46	174.05	218.71	-44.65	2	2
05/14	310.25	170.63	218.71	-48.07	3	3
05/21	316.46	174.05	218.71	-44.65	2	4
05/28	306.72	168.69	218.71	-50.01	4	5
06/01	301.86	166.02	218.71	-52.68	5	6
06/07	277.51	152.63	218.71	-66.07	6	7
06/14	265.34	145.93	218.71	-72.77	7	8
06/21	223.96	123.17	218.71	-95.53	8	9
06/28	180.14	99.07	218.71	-119.63	9	10

Table 8. Impacts of fertilization under below normal rainfall scenario.

Fertilizer lb/acre	Yield lb	Nitrogen Stress Days	Gross Returns $/acre	Variable Cost $/acre	Profits $/acre	Avg. Net Return Ranking	SDRF Ranking
Elemental N							
0	175.27	14.6	96.39	211.81	-115.41	9	9
10	219.09	0	120.49	214.11	-93.62	4	4
20	219.09	0	120.49	216.41	-95.91	6	6
22-08-02							
75	219.09	0	120.49	210.81	-90.31	1	1
100	219.09	0	120.49	212.16	-91.66	2	2
125	219.09	0	120.49	213.51	-93.01	3	3
28-11-04							
100	219.09	0	120.49	216.06	-95.66	5	5
125	219.09	0	120.49	218.38	-97.88	7	7
150	219.09	0	120.49	220.70	-100.20	8	8

Table 9. Impacts of fertilization under above normal rainfall scenario.

Fertilizer lb/acre	Yield lb	Nitrogen Stress Days	Gross Returns $/acre	Variable Cost $/acre	Profits $/acre	Avg. Net Return Ranking	SDRF Ranking
Elemental N							
0	150.93	41.5	83.01	211.81	-128.79	9	9
10	299.42	5.8	164.68	214.11	-49.42	8	8
20	316.46	0	174.05	216.41	-42.35	5	5
22-08-02							
75	316.46	0	174.05	210.81	-36.76	1	2
100	316.46	0	174.05	212.16	-38.11	2	1
125	316.46	0	174.05	213.51	-39.45	3	3
28-11-04							
100	316.46	0	174.05	216.06	-42.01	4	4
125	316.46	0	174.05	218.38	-44.33	6	6
150	316.46	0	174.05	220.70	-46.65	7	7

Table 10. Economic benefits of best management practices under below normal rainfall conditions.

Population (Plants/acre)	Planting Date	Fertilization (lbs/acre)	Yield (lb/acre)	Gross Returns ($/acre)	Variable Cost ($/acre)	Profit ($/acre)
32,469	05/01	75 (22-08-02)	219.09	120.49	208.41	-87.91
32,469	05/07	75 (22-08-02)	216.65	119.15	208.41	-89.25
32,469	05/14	75 (22-08-02)	216.65	119.15	208.41	-89.25
32,469	05/01	100(22-08-02)	219.09	120.49	209.76	-89.26
32,469	05/07	100(22-08-02)	216.65	119.15	209.76	-90.60
32,469	05/14	100(22-08-02)	216.65	119.15	209.76	-90.60
32,469	05/01	125 (22-08-02)	219.09	120.49	211.11	-90.61
32,469	05/07	125 (22-08-02)	216.65	119.15	211.11	-91.95
32,469	05/14	125(22-08-02)	216.65	119.15	211.11	-91.95
35,469	05/01	75 (22-08-02)	219.09	120.49	209.31	-88.81
35,469	05/07	75 (22-08-02)	219.09	120.49	209.31	-88.81
35,469	05/14	75 (22-08-02)	219.09	120.49	209.31	-88.81
35,469	05/01	100(22-08-02)	219.09	120.49	210.66	-90.16
35,469	05/07	100(22-08-02)	219.09	120.49	210.66	-90.16
35,469	05/14	100(22-08-02)	219.09	120.49	210.66	-90.16
35,469	05/01	125 (22-08-02)	219.09	120.49	212.01	-91.51
35,469	05/07	125 (22-08-02)	219.09	120.49	212.01	-91.51
35,469	05/14	125(22-08-02)	219.09	120.49	212.01	-91.51
36,469	05/01	75 (22-08-02)	224.52	123.48	209.61	-86.12
36,469	05/07	75 (22-08-02)	216.65	119.15	209.61	-90.45
36,469	05/14	75 (22-08-02)	219.09	120.49	209.61	-89.11
36,469	05/01	100(22-08-02)	224.52	123.48	210.96	-87.47
36,469	05/07	100(22-08-02)	219.09	120.49	210.96	-90.46
36,469	05/14	100(22-08-02)	219.09	120.49	210.96	-90.46
36,469	05/01	125 (22-08-02)	224.52	123.48	212.31	-88.82
36,469	05/07	125 (22-08-02)	219.09	120.49	212.31	-91.81
36,469	05/14	125(22-08-02)	219.09	120.49	212.31	-91.81

Table 11. Economic benefits of best management practices under above normal rainfall conditions.

Population (Plants/acre)	**Planting Date**	**Fertilization (lbs/acre)**	**Yield (lb/acre)**	**Gross Returns ($/acre)**	**Variable Cost ($/acre)**	**Profit ($/acre)**
35,469	05/01	75 (22-08-02)	316.46	174.05	209.31	-35.25
35,469	05/07	75 (22-08-02)	314.03	172.71	209.31	-36.59
35,469	05/14	75 (22-08-02)	316.46	174.05	209.31	-35.25
35,469	05/01	100(22-08-02)	316.46	174.05	210.66	-36.60
35,469	05/07	100(22-08-02)	314.03	172.71	210.66	-37.94
35,469	05/14	100(22-08-02)	316.46	174.05	210.66	-36.60
35,469	05/01	125 (22-08-02)	316.46	174.05	212.01	-37.95
35,469	05/07	125 (22-08-02)	314.03	172.71	212.01	-39.29
35,469	05/14	125(22-08-02)	316.46	174.05	212.01	-37.95
40,469	05/01	75 (22-08-02)	318.90	175.39	210.81	-35.41
40,469	05/07	75 (22-08-02)	316.46	174.05	210.81	-36.75
40,469	05/14	75 (22-08-02)	318.90	175.39	210.81	-35.41
40,469	05/01	100(22-08-02)	318.90	175.39	212.16	-36.76
40,469	05/07	100(22-08-02)	316.46	174.05	212.16	-38.10
40,469	05/14	100(22-08-02)	318.90	175.39	212.16	-36.76
40,469	05/01	125 (22-08-02)	318.90	175.39	213.51	-38.11
40,469	05/07	125 (22-08-02)	316.46	174.05	213.51	-39.45
40,469	05/14	125(22-08-02)	318.90	175.39	213.51	-38.11
44,469	05/01	75 (22-08-02)	322.33	177.28	212.01	-34.72
44,469	05/07	75 (22-08-02)	316.80	174.24	212.01	-37.77
44,469	05/14	75 (22-08-02)	318.90	175.39	212.01	-36.62
44,469	05/01	100(22-08-02)	322.33	177.28	213.36	-36.07
44,469	05/07	100(22-08-02)	318.90	175.39	213.36	-37.96
44,469	05/14	100(22-08-02)	322.33	177.28	213.36	-36.07
44,469	05/01	125 (22-08-02)	322.33	177.28	214.71	-37.42
44,469	05/07	125 (22-08-02)	318.90	175.39	214.71	-39.31
44,469	05/14	125(22-08-02)	322.33	177.28	214.71	-37.42