COMPARISON OF ALTERNATIVE IRRIGATED COTTON MANAGEMENT PRACTICES UNDER HIGHER ELECTRICITY PRICES

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Abstract

The impact of expected higher energy cost on irrigated cotton profitability is examined for two production strategies. The first, assumed producers maximize expected profits based upon an expected price, whereas the second assumed producers maximize a hedonic price function. Hedonic production was more profitable than non-hedonic, and used fewer inputs.

Introduction

Though the deregulation of the electric power industry in Texas promises lower electric prices for consumers in aggregate, a number of studies indicate deregulation may lead to higher prices in rural areas of the country due to the limited ability of many rural regions to import electricity from producers outside their region (Northcutt, 2001, Johnson, 1999; Chernoff and Sanchez, 1998). Increasing energy cost would further decrease the minimal profit margins of many energy dependent irrigated agricultural producers (Texas Tech University, 2001). Johnson (1999) determined that irrigated agriculture comprises 38% of all energy use in the Texas High Plains (THP) and that 55% of all irrigated THP farms use electricity as their power source. Moreover 60% of all irrigated acres in the region are in cotton production (Texas Agricultural Statistical Service, 2000). Increased electricity prices will increase irrigation costs and decrease farm profits for those producers utilizing electricity as their power source. A traditional management strategy for improving profitability of irrigated cotton production systems is to increase per acre cotton lint yield by increasing the use of inputs. However, recent studies indicate that potential profitability gains exist from diversifying management practices to include consideration of cotton lint quality when identifying profit-maximizing input use regimes (Denning et al., 2001; Green et al., 1999; Morrow and Krieg, 1990). But, the relative additional profitability gains or potential losses from these management practices, given the assumption of higher electricity prices is unknown.

The primary objective of this study is to evaluate the economic importance of altering irrigated cotton management practices from a yield focus to a quality focus for purposes of mitigating expected increases in electric energy prices due to deregulation. Higher energy costs will increase the cost of lifting groundwater and pressurizing irrigation systems. We specifically examine how per acre gross revenue and selected irrigation related variable cost items optimally respond to potential increases in energy cost under two alternative management strategies. The first strategy assumes producers manage for lint quality attributes, and the second management strategy assumes producers manage for lint yield only, and ignore the impact their input use rates have on lint quality. We also examine the capacity of revenue premiums for increased lint quality to partially, or totally, offset yield-related revenue decreases that occur if irrigation application rates are reduced. The sensitivity of the results to climatic conditions is also examined.

Data and Methods

Data Description

The data used to estimate the impact of per acre water and fertilizer input levels on cotton quality attributes was collected by Allen and Krieg (2000) from three field experiments conducted in Lubbock County, Texas, in 1997, 1998 and 1999. This data set contained 1,033 paired observations on lint yield, seed yield, turnout, micronaire, staple length, and fiber strength values corresponding to varying irrigation water/nitrogen application rates, phosphorous fertilizer application methods and rates, seed varieties, and weather conditions (i.e. accumulated heat units and rainfall during the cotton growing season).

Supplemental irrigation water, applied through a LEPA system, ranged from 3 to 14 acre-inches. Nitrogen was applied through the irrigation system at a rate of 6 pounds per acre-inch of applied water as recommended by Morrow and Krieg (1990). Three different phosphorous application methods were evaluated: pre-plant, side-dress, and fertigation at rates ranging from 0 to 73 pounds per acre. All water/fertilization application combinations were repeated for eleven cottonseed varieties: Paymaster HS 26, Paymaster HS 200, Delta Pine 2156, Paymaster Tejas, HOL 101, HOL 338, All-Tex Atlas, AFD Explorer, AFD Rocket, All-Tex Toppick, and All-Tex Xpress.

Temperature and rainfall measurements were collected at the research site. The experiment received less-than-average rainfall (8.5 inches) and close-to-average heat unit accumulation (1161C) in 1997. In 1998, a dry year, the plots received little rainfall (5.4 inches) and a relatively high heat unit accumulation (1544C). During 1999, the experiment received below average heat unit accumulation (1022C) and rainfall (6.3 inches). Heat unit accumulations were calculated from daily temperature data during the normal cotton-growing period in the Texas High Plains, which extends from May to September.

Cotton yield and lint quality attributes were measured at each experimental plot by hand harvesting all cotton bolls within a sample area of 1/1000 of an acre. The harvested bolls were ginned and a sample of the ginned cotton from each plot was sent to the International Textile Center of Texas Tech University to determine the values of its lint quality attributes. Staple length, strength, and micronaire were measured using High Volume Instrument (HVI) tests. A complete discussion of the empirical data is found in Allen and Krieg (2000).

Modeling Procedure

In previous research, Denning *et al* (2001) used Allen and Kreig's data set in an econometric analysis that estimated the impact water application level, fertilization level, and climatic condition have on per acre cotton lint yield, and the seven lint quality attributes for which price premiums and discounts are applied. This study merges their estimated production relationships for cotton quality attributes with price estimates for yearly average lint price, and premiums and discounts paid for specific cotton quality attributes. The premium and discount values were estimated by the Daily Price Estimation System (DPES) for the 1998 marketing year. The DPES is a computerized, econometrically based, price analysis system maintained and operated by the Department of Agricultural and Applied Economics at Texas Tech University. The DPES uses a hedonic modeling approach to statistically estimate the quality premium and discount values for the West Texas and East Texas/Oklahoma cotton marketing regions on a daily basis. In any given marketing year the DPES estimates daily and average annual premiums and for seven lint quality attributes: (1) leaf grade; (2) color grade; (3) staple length; (4) strength; (5) micronaire; (6) bark; and (7) other extraneous matter. The 1998 DPES marketing year equation was selected because it provided a set of premium and discount estimates for changes in quality characteristic measures that are close to their respective average value for the 1993-2001 period (Hoelscher et al.,1999; Misra, 2001).

Hedonic Optimization Framework

Nonlinear programing techniques were required to simulate the relationship between input use levels, changes in lint quality attributes, and the ultimate per pound price received by producers because the DPES uses a set of non-linear equations to express the relationships between cotton price premiums/discounts and cotton fiber quality. Hence, the premium and discount estimates are non-linear functions of the lint quality characteristics, which are in turn a nonlinear function of input use levels, seed variety, and weather conditions. Models that explicitly consider implicit quality attributes values are commonly referred to as hedonic models. In conceptual terms, the hedonic optimization model has the following structure:

(1) Max Profit = TR - WRC - FC

Where:

TR	=	total revenue, and is equal to P^H*Y and P^H is hedonic price and Y is lint yield per acre,
P^H	=	F(micronaire, strength, staple| other quality attributes fixed),
WRC	=	G(applied irrigation water, electricity use, liquid nitrogen)
FC	=	H(per acre cost of all fixed inputs, and those variable inputs not in WRC).

Subject to:

(2)	Y	=	I(water, liquid nitrogen, seed variety, heat units, rainfall | other inputs fixed),
(3)	Micronaire	=	J(water, liquid nitrogen, seed variety, heat units, rainfall | other inputs fixed),
(4)	Strength	=	K(water, liquid nitrogen, seed variety, heat units, rainfall | other inputs fixed),
(5)	Staple	=	L(water, liquid nitrogen, seed variety, heat units, rainfall | other inputs fixed),
(6)	Water	=	M(electricity| irrigation technology fixed),
(7)	Nitrogen	=	N(electricity| irrigation technology fixed), and
(8)	Water	≤	maximum acre-inch/per acre irrigation system can apply in growing season.

Equation 1 is the objective, or profit, function that is to be maximized. Per acre profit is maximized when the difference between total revenue (TR) and the sum of water related variable costs (WRC) and fixed cost (FC) is as large as possible. To isolate the impact changing electric rates are likely to have on cotton profitability, for a given irrigation technology, only those input cost items that vary with per acre energy use are allowed to vary in this analysis, and all other variable cost items plus the traditional fixed cost items (machinery, irrigation system, land, etc.) are summed into an aggregate fixed cost category. In the hedonic model specification per acre TR is the product of the per acre quantity of lint produced (Y) and hedonic lint price (P^H). Equations 2, 3, 4, and 5 capture the impact that changes in the per acre quantity of applied irrigation water, liquid nitrogen, heat units, and rainfall have on lint yield and the three most economically important qualitative attributes, micronaire, strength, and staple. The values for the three lint quality measures determine the hedonic price per pound of lint (P^H) which is used to calculate profit in equation 1. In this analysis, the four other lint quality attributes (leaf grade, color grade, bark, and other extraneous matter) are assumed to be at their respective base quality levels, the level for which no price discount is deducted or premium is paid. The specific functional forms for equations 2, 3, 4, and 5 are reported in Denning *et al* (2001). Equations 6 and 7 explicitly recognize that the quantity of irrigation water and nitrogen (liquid form) applied are both a function of the energy use level. Consistent with the empirical data used to estimate the lint yield and lint quality response to applied water and nitrogen, the hedonic optimization model assumes fertigation is the technology used to apply nitrogen to the crop. Equation 8 prevents the per acre quantity of applied irrigation water from exceeding the capacity of the irrigation system. Variable cost, per-acre inch of applied water (C_W) is calculated as:

(9) C_W = Pumping Cost + Machinery Cost

= 0.164*[Pumping Lift+{2.31*Pumping Pressure}]*ECOST/KWH + [0.003234*Pumping Lift]

As shown in Equation 9, pumping cost is a function of electricity cost per kwh (ECOST), pump lift, and pumping pressure. Machinery cost accounts for the maintenance, lube, and repairs of irrigation equipment. Per acre liquid nitrogen cost, the other irrigation related variable cost, is calculated as acre-inches of applied water multiplied by pounds of liquid nitrogen applied per acre-inch applied water, and this product is then multiplied by the per pound cost of liquid nitrogen.

Non-Hedonic Optimization Framework

The non-hedonic optimization framework is conceptually similar to the hedonic framework with two important exceptions. First, the lint quality equations (equations 3, 4, 5) are excluded from the constraint set. The second major change is that price is no longer endogenous to the model. The endogenous price variable in Equation 1 (P^H) is replaced with an expected fixed price based on producer expectations. Under this modeling framework, the producer assumes expected per unit price does not very with input use. Because the producer fails to consider the impact input use has on quality, and hence price received at sale, it is possible for non-hedonic managers to have high per acre lint yields but receive a low per pound market price under specific weather patterns and/or input use levels. In the non-hedonic optimization model the average lint price for the 1998 marketing year is used ($0.5807/lb) as producer expected price. The 1998 average marketing year price was received when all seven lint quality attributes were at their respective base values, where no price discount is deducted for below average quality characteristics nor a price premium paid for above average quality characteristics.

Representative Farm Assumptions

The analytic results are for a typical farm on the THP that uses seed variety Paymaster HS 26, the most commonly used seed variety. Thus the seed variety variable in equations 2, 3, 4, and 5 is fixed in this analysis. The average phosphorous pre-plant application rate of 40 pounds per acre is applied. Irrigation water is applied by a LEPA irrigation system that can apply a maximum of 15 acre-inches of water, per acre, in the growing season. Whole farm cotton budgets for the region were consulted and fixed costs (including all other non-irrigation related variable costs) were estimated to be $381 per acre (USDA, 2000). With respect to the irrigation related variable cost items, per pound nitrogen cost was set at the average 2001 price of $0.4125 for nitrogen ($264 per ton of 32% solution, (NASS, 20001)) and is assumed to be applied at the recommend rate of 6 pounds per acre inch of applied water (Morrow and Krieg, 1990). The baseline electricity rate was set at $.0718/KWH, the average commercial price in 2000 for the THP. Pumping lift and pumping pressure were respectively set at 200 feet and 16.5 PSI, based on information provided by the High Plains Water District (1998).

Weather Scenarios

For purposes of examining the impact climatic conditions have on the relative profitability of hedonic versus non-hedonic management, both management strategies were examined for three weather scenarios. The three scenarios were derived after reviewing the historic temperature and precipitation pattern for Lubbock county (National Oceanic and Atmospheric Administration, 2000; National Weather Service, 2000). The first scenario represents an average weather year. In an average weather year the cotton crop receives 1275 heat units and 9.85 inches of rainfall within the growing season (May-September). The second weather scenario is representative of a cool and wet growing season where the crop receives 1100 heat units and

12.34 inches of rainfall. The third, and final, scenario is for a hot and dry growing season where the crop receives 1400 heat units and only 5.62 inches of rainfall.

Electricity Cost Scenarios
Given the uncertainty surrounding future electric rates in rural areas we present the relative profitability measures of the two alternative management scenarios, for four alternative price scenarios: (1) the average rate paid by commercial customers in 2000 ($.0718/kwh); (2) a 10% rate increase; (3) a 30% rate increase; and a 45% rate increase.

Results

This section presents profit comparisons for both hedonic and non-hedonic profit management for the three weather scenarios and four potential electricity cost rates. Across all weather and price scenarios, hedonic management is never less profitable, and is generally more profitable, than non-hedonic management. From a theoretical perspective this is not surprising because, at its most basic level, hedonic profit maximization is a means to provide producers with more production options , where one of those options remains the non-hedonic management choice. Even though a non-hedonic producer often mistakenly manages for an incorrect expected market price, the actual per pound price the producer receives is a function of the lint's hedonic quality attributes at the time of sale. Thus, while unlikely, it is possible that both management strategies can generate identical quality characteristics in some situations.

Average Weather Conditions
Under average weather conditions hedonic profit management generated higher profits than non-hedonic management. Moreover, as electricity price is increased, the value of hedonic management increases relative to non-hedonic management. The hedonic benefit ranges from $5.32 per acre at the baseline electric rate and increases to $8.69 per acre when the baseline electric rate is increased by 45% (Table 1). Despite the fact that hedonic management provides a higher market price than non-hedonic management ($0.56/lb versus $0.55/lb) gross revenue is higher for non-hedonic management due to higher lint yields. Lint yields are higher for non-hedonic management because the non-hedonic manager applies the maximum per acre quantity of water (15 acre-inches/acre), whereas the hedonic manager applies less water. Even though the hedonic manager generates slightly less gross revenue than the non-hedonic manager, anywhere from $2.95 to $5.03 per acre (Table 2) depending upon the cost of electricity, the hedonic manger is more profitable than the non-hedonic manager because irrigated related variable costs are less under hedonic management ($8.27 to $13.71 per acre). The hedonic management cost savings associated with applying less water, in combination with a slightly higher lint price are more than sufficient to offset the slight yield disadvantage of hedonic management.

Cool and Wet Weather Conditions
The overall empirical results for the cool and wet growing season scenario are generally similar to the average weather scenario except that the magnitude of the economic benefit is considerably larger for hedonic management. The hedonic profit management benefit ranges from $70.03 to $78.08 per acre (Table 3). As before the non-hedonic manager has higher yields because approximately 5 more inches of water is applied, per acre, than under hedonic management. While the additional water application serves to increase lint yield it does so at the expense of sacrificing lint quality. The per pound market price for lint under hedonic management is $0.58 regardless of electricity cost, but never exceeds $0.51 per pound under non-hedonic management (Table 3). Despite lower lint yields under hedonic management, the superior quality of the lint more than offsets the yield reduction and hedonic management generates between $33.84 and $45.66 more revenue than the non-hedonic management (Table 4). Due to lower water use irrigation related variable costs are considerably less for the hedonic manager, ranging from $32.43 to $36.19 less per acre, depending upon electricity price. Assuming a 45% increase in electricity cost, electricity expenditure by the hedonic manager is $20.47 less per acre than for the non-hedonic manager (table 2).

Hot and Dry Weather Conditions
The hot and dry weather scenario provides a situation where the hedonic management solution is identical to the non-hedonic solution. Per acre profit is identical because the hot weather in combination with low rainfall necessitates that both managers maximize their use of applied water (both apply the maximum of 15 acre-inches per acre). Even though both managers apply the maximum quantity of available water, yields are as much 20% lower than they were in the prior two weather scenarios. This suggests that the additional revenue generated by increasing lint yields at low per acre production levels, is more profitable than managing for quality when yields are low due to water supply scarcity.

Summary and Conclusions

The optimization results revealed significant differences between hedonic and non-hedonic profitability. Not surprisingly, as economic theory would suggest, hedonic management is more profitable than non-hedonic profit maximization given the modeling assumptions. However, the magnitude of increased profitability value for hedonic management in a cool wet year was surprising. Hedonic management generated $78.08 dollars more per acre than non-hedonic management. This scenario clearly illustrates the impact input management decisions can have on lint yield, lint quality, lint price, and production cost. The per acre cost savings associated with irrigation related variable cost under hedonic management increased with increases in the cost of electricity , and is $13.71 under average weather conditions and a 45% increase in the price of electricity (table 2). Moreover, 56.6% of the cost savings is the direct result of lower electricity expenditures.

While these empirical results are consistent with the hedonic valuation literature, the magnitude of the reported differences between hedonic versus non-hedonic profit maximization are conditioned on the experimental data used to quantify the lint yield and lint quality response to applied water and nitrogen, and the 1998 DPES equation. The production response models were estimated by Denning et al. (2001), using three years of experimental data collected under intensive management practices in one Texas county. The reported results for lint yield and quality characteristics, and overall profitability, will likely vary with the various soil types and management practices of the Texas High Plains. However, from a theoretical perspective, hedonic profit maximization will always generate a per acre profit level greater than or equal to non-hedonic profit maximization for any given set of management practices. Finally, the magnitude of the empirical results were derived under the assumption that the producer had perfect knowledge of growing season rainfall and accumulated heat units. This assumption is heroic given current weather forecasting capabilities. But with the continuing advances in precision agriculture technology, the need and economic value of perfect weather forecasts will be greatly diminished, because precision agricultural techniques allow management to continuously adjust input use levels to compensate for changing weather conditions and facilitate hedonic profit maximization. Clearly additional economic research is needed to determine the on-farm plausibility of managing for hedonic characteristics. However, the economic incentive is there, and the agricultural payoff could be enormous.

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Table 1. Per Acre Revenue and Cost Comparisons of Hedonic Versus Non-Hedonic Cotton Management for a LEPA Irrigated Farm with a 200 Foot Pump: Average Weather Conditions

Item	Base Cost ($0.0718/kwh)	Percent Energy Cost Increase 10%	30%	45%
Profit Hedonic ($/ac)	209.27	205.78	198.85	193.71
Profit Non-Hedonic ($/ac)	203.95	199.74	191.33	185.02
Non-Hedonic Profit Loss ($/ac)	-5.32	-6.04	-7.52	-8.69
Applied Water: Hedonic (ac in/ac)	13.60	13.48	13.26	13.09
Applied Water: Non-Hedonic (ac in /ac)	15.00	15.00	15.00	15.00
Price Hedonic ($/lb)	0.56	0.56	0.56	0.56
Price Non-Hedonic ($/lb)	0.55	0.55	0.55	0.55
Yield Hedonic (lbs/ac)	1,156.55	1,153.93	1,148.81	1,145.07
Yield Non-Hedonic (lbs/ac)	1,183.66	1,183.66	1,183.66	1,183.66
Gross Revenue Hedonic ($/ac)	647.52	647.10	646.19	645.45
Gross Revenue Non-Hedonic ($/ac)	650.48	650.48	650.48	650.48
Hedonic Irrigataion Related Cost ($/ac)	80.61	83.68	89.70	94.10
Non-Hedonic Irrigation Related Cost ($/ac)	88.89	93.09	101.50	107.81

Note: In average weather conditions the crop receives 1275 heat units and 9.85 inches of rainfall over the growing season.

Table 2. Per Acre Differences in Gross Revenue, Irrigation Related Production Costs, and Profit for Non-Hedonic Cotton Production Relative to Hedonic Production for a LEPA Irrigated Farm with a 200 Foot Pump Lift: Average Weather Conditions

Item	Base Cost ($0.0718/kwh)	Percent Energy Cost Increase 10%	30%	45%
Increased Gross Revenue ($/ac)	2.95	3.37	4.29	5.03
Change in Irrigation Related Costs ($/ac)				
Increased Energy Cost ($/ac)	3.91	4.68	6.36	7.76
Increased Irr. Maint. Cost ($/ac)	0.90	0.98	1.13	1.23
Increased Fertilizer Cost ($/ac)	3.46	3.75	4.32	4.72
Total All Extra Irrig. Related Costs ($/ac)	8.27	9.41	11.81	13.71
Non-Hedonic Profit Reduction ($/ac)	-5.32	-6.04	-7.52	-8.69

Note: In average weather conditions the crop receives 1275 heat units and 9.85 inches of rainfall over the growing season.

Table 3. Per Acre Revenue and Cost Comparisons of Hedonic Versus Non-Hedonic Cotton Management for a LEPA Irrigated Farm with a 200 Foot Pump Lift: Below Average Temperature and Above Average Rainfall

Item	Base Cost ($0.0718/kwh)	Percent Energy Cost Increase 10%	30%	45%
Profit Hedonic ($/ac)	242.72	239.83	234.45	229.96
Profit Non-Hedonic ($/ac)	164.63	163.78	161.28	159.93
Non-Hedonic Profit Loss ($/ac)	-78.08	-76.06	-73.17	-70.03
Applied Water: Hedonic (ac in/ac)	9.38	9.32	9.21	9.13
Applied Water: Non-Hedonic (ac in /ac)	14.85	14.68	14.40	14.16
Price Hedonic ($/lb)	0.58	0.58	0.58	0.58
Price Non-Hedonic ($/lb)	0.50	0.50	0.51	0.51
Yield Hedonic (lbs/ac)	1,141.28	1,139.83	1,137.14	1,135.28
Yield Non-Hedonic (lbs/ac)	1,221.40	1,220.34	1,218.36	1,216.54
Gross Revenue Hedonic ($/ac)	656.31	656.09	655.88	655.28
Gross Revenue Non-Hedonic ($/ac)	610.65	613.33	617.84	621.43
Hedonic Irrigataion Related Cost ($/ac)	55.58	57.83	62.29	65.60
Non-Hedonic Irrigation Related Cost ($/ac)	88.01	91.12	97.42	101.79

Note: In the below average temperature and high rainfall weather scenario the crop receives 1100 heat units and 12.34 inches of rainfall over the growing season.

Table 4. Per Acre Differences in Gross Revenue, Irrigation Related Production Costs, and Profit for Non-Hedonic Cotton Production Relative to Hedonic Production for a LEPA Irrigated Farm with a 200 Foot Pump Lift: Below Average Temperature and Above Average Rainfall

Item	Base Cost ($0.0718/kwh)	Percent Energy Cost Increase 10%	30%	45%
Increased Gross Revenue ($/ac)	-45.66	-42.77	-38.05	-33.84
Change in Irrigation Related Cost ($/ac)				
Increased Energy Cost ($/ac)	15.34	16.54	18.92	20.47
Increased Irr. Maint. Cost ($/ac)	3.54	3.47	3.36	3.26
Increased Fertilizer Cost ($/ac)	13.54	13.28	12.85	12.46
Total All Extra Irrig. Related Costs ($/ac)	32.43	33.29	35.23	36.19
Non-Hedonic Profit Reduction ($/ac)	-78.08	-76.06	-73.17	-70.03

Note: In the below average temperature and high rainfall weather scenario the crop receives 1100 heat units and 12.34 inches of rainfall over the growing season.

Table 5. Per Acre Revenue and Cost Comparisons of Hedonic Versus Non-Hedonic Cotton Management for a LEPA Irrigated Farm with a 200 Foot Pump Lift: Above Average Temperature and Below Average Rainfall

Item	**Base Cost**	**Percent Energy Cost Increase**		
	($0.0718/kwh)	**10%**	**30%**	**45%**
Profit Hedonic ($/ac)	133.86	129.65	121.24	114.93
Profit Non-Hedonic ($/ac)	133.86	129.65	121.24	114.93
Non-Hedonic Profit Loss ($/ac)	0.00	0.00	0.00	0.00
Applied Water: Hedonic (ac in/ac)	15.00	15.00	15.00	15.00
Applied Water: Non-Hedonic (ac in /ac)	15.00	15.00	15.00	15.00
Price Hedonic($/lb)	0.59	0.59	0.59	0.59
Price Non-Hedonic($/lb)	0.59	0.59	0.59	0.59
Yield Hedonic(lbs/ac)	979.43	979.43	979.43	979.43
Yield Non-Hedonic(lbs/ac)	979.43	979.43	979.43	979.43
Gross Revenue Hedonic ($/ac)	580.39	580.39	580.39	580.39
Gross Revenue Non-Hedonic ($/ac)	580.39	580.39	580.39	580.39
Hedonic IrrigataionRelated Cost ($/ac)	88.89	93.09	101.50	107.81
Non-Hedonic IrrigationRelated Cost ($/ac)	88.89	93.09	101.50	107.81

Note: In the above average temperature and low rainfall weather scenario the crop receives 1400 heat units and 5.62 inches of rainfall over the growing season.