IMPACT OF QUALITY ON THE PROFITABILITY OF IRRIGATED COTTON PRODUCTION ON THE TEXAS HIGH PLAINS

Megan L. Denning, Octavio A. Ramirez and Carlos Carpio
Texas Tech University
Lubbock, TX

Abstract

Production function models for cotton lint yield, seed yield, and lint quality characteristics (e.g. micronaire, staple length, and fiber strength) are developed. The models are used to evaluate the effect of lint prices, seed prices, lint quality premiums/discounts, variable input costs, and weather conditions on a set of profit-maximizing crop management decisions involving variety, fertilizer application method, and input (water/nitrogen and phosphorous fertilizer) use levels. Both expected returns and variability of profit are considered in the analysis. The main conclusion of the study is that knowledge and consideration of the effect of management decisions on lint quality can substantially increase expected profitability and reduce profit variation.

Introduction

The Texas High Plains is one of the most important cotton producing areas of the U.S., accounting for nearly 20% of the total U.S. production during the past decade. Farm-level yields in the Texas High Plains are significantly influenced by a few critical factors including weather conditions, irrigation water application rates, fertilization methods and application rates, and variety selection. These factors need to be collectively considered and managed by producers. Due to the existence of significant premiums and discounts for lint quality, producers need a better understanding of the determinants of cotton quality, the agronomic tradeoffs between yield and quality, and the effect of weather on these two outputs.

A common management strategy for increasing profits has been to improve lint yields by adopting new varieties or technologies, which often results in higher costs of production (Bradow and Davidionis, 2000). Such a strategy is becoming less feasible for cotton producers on the Texas High Plains due to low cotton prices and a reduced availability of irrigation water. A second management strategy that has been used to increase profits is to find more economically efficient input utilization by considering the relationships between yields and a few critical factors of production. Green et al. (1999) analyzed the response of cotton lint yields to water supply, fertilizer application method, and nitrogen-to-phosphorus application ratio. The study found that lint yields increase with water application, that a nitrogen-to-phosphorus ratio of 5:3 produces the highest yields, and that fertigation provides the strongest yield response to additional phosphorus application. Morrow and Krieg (1990) clarified the importance of timing in nutrient application for improving cotton lint yields. The study revealed that water supply during the fruiting season is more important in determining yields than water availability prior to fruiting, and that pre-plant nitrogen availability influences the lint yield response to water supply. The possibility of increasing profits by considering the effects of management decisions on both lint yields and the quality of cotton produced has been largely ignored in the literature.

The reality of agronomic tradeoffs between quantity and quality of cotton produced under different management regimes and the potential existence of interactions between factors of production and weather variables generates the need for a comprehensive evaluation of these relations. This study addresses that need by developing six production response functions that simultaneously describe the relationships between critical factors of production and cotton output (e.g. lint yield, seed yield, micronaire, strength, staple, and turnout) in the Texas High Plains, under different weather (e.g. heat unit and rainfall) scenarios. The production functions are used to identify the set of management decisions (variety, fertilizer application method, and irrigation water/nitrogen and phosphorous fertilizer application rates) that maximize profits, given cotton lint prices, quality premiums/discounts and relevant production costs. The functions are also used to evaluate the changes in expected profitability and profit variation caused by consideration of the effect of management decisions on the quality of the cotton being produced.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:208-216 (2001)
National Cotton Council, Memphis TN

Methods and Procedures

Data Description

The data set for this research was collected from three field experiments conducted in Lubbock County, Texas, in 1997, 1998 and 1999. It consists of 1033 lint yield, seed yield, turnout, micronaire, staple length, and fiber strength value observations corresponding to varying irrigation water/nitrogen application rates, phosphorous fertilizer application methods and rates, varieties, and weather conditions (e.g. heat units and rainfall during the cotton growing season). Three different phosphorus application methods were evaluated: pre-plant, side-dress, and fertigation. A control method, where the plots did not receive supplemental phosphorus, was also evaluated. Under pre-plant and side-dress, the fertilizer application rate was held constant at 40 pounds of phosphorus per acre. Under fertigation, phosphorus was applied at varied rates ranging from 0 to 73 pounds per acre. Supplemental irrigation water, applied through a LEPA system, ranged from 3 to 14 acre-inches. Nitrogen was applied through the water at a rate of 25 kg of nitrogen per hectare to every 100 mm of water per hectare, as recommended by Morrow and Krieg (1990). All water/nitrogen and phosphorus 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, approximately 35 miles southwest of Lubbock. 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 very 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). The three observed heat unit and rainfall pairs were used to estimate the six production functions.

The temperature data used for profit simulations was from Lubbock, Texas from 1914 to 1999. Heat unit accumulation was calculated from daily temperature data during the normal cotton-growing period in the Texas High Plains, which extends from May to September. The relative frequency distribution of the 1914-1999 May-to-September heat unit accumulation data is presented in Figure 1. May-to-September rainfall data was also obtained for Lubbock County from 1911 to 1999. The relative frequency distribution of the 1911-1999 May-to-September rainfall data is presented in Figure 2.

Cotton yields 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 at a plot gin. 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 lint quality attributes. Staple, strength, and micronaire were measured using High Volume Instrument (HVI) tests.

Response Functions, Production Surfaces and Contour Maps

The six production response functions were estimated using a Seemingly Unrelated Least Squares regression procedure, which takes advantage of the correlation between the dependent variables in the lint yield, seed yield, strength, staple, micronaire, and turnout equations. Each function was initially specified to include an intercept, 80 independent variables, and an error term. The quantitative independent variables included in the six model specifications were heat units (degrees celsius), rainfall (inches), irrigation water (acre-inches), and phosphorus fertilizer (pounds per acre). Binary or qualitative independent variables were included in the production response functions as dummy variables. These accepted a value of zero or one depending upon the replicate, fertilizer application method and variety utilized. The production response functions also contained constructed independent variables to account for potential interactions between quantitative and qualitative independent variables. These interactions allowed for different slopes of the production response surfaces with respect to irrigation water and phosphorus application rates, depending upon the weather conditions, fertilizer application method and variety. This allowed for different dependent variable response rates to changes in quantitative variables, depending on the fertilizer application method, variety and prevailing weather. It also accounted for any potential response rate difference due to the replication. The significance of each individual parameter was evaluated using two-tailed t-tests. F-tests were used, when necessary, to assess the statistical significance of groups of parameters. The results from the t- and F-tests were used to determine which independent variables to include in each of the six final models.

The final models (e.g. estimated response functions) were used to generate graphical response surfaces depicting lint yield response to water and phosphorus application under five different weather scenarios created by pairing average, maximum, and minimum observed rainfall and heat unit values. Contour maps were generated from the final micronaire, staple and strength models and used to evaluate the response of these three quality attributes to different phosphorus and water application combinations under the five previously discussed weather scenarios.

Profit Equation

A hedonic profit equation predicts the per-acre profits obtained under a variety of management scenarios, considering the quantity, as well as the quality, of the product. In this case, the relevant hedonic profit equation calculated the difference between total costs and total (gross) revenues, where revenues were determined by utilizing a lint price that represented a base price applied to cotton lint with baseline quality values adjusted by premium and discount values associated with predicted quality attributes. The annual averages of the base price and of the premium/discount estimates from the Texas Tech University Daily Price Estimation System (DPES) for the years of 1994 to 1998 were used in the analysis. The DPES is a set of non-linear models of the relationships between cotton price and the quality attributes of the cotton fiber. Therefore, the premium and discount estimates (Table I) are non-linear functions of the different quality values. A fixed price per pound of seed was used in the profit equation, which was calculated by taking the average of the seed prices reported by the National Agricultural Statistics Service from 1994 to 1998 adjusted for inflation using the 1999 producer price index. To determine total gross revenues, lint price was multiplied by the predicted level of lint yield and was added to the result of seed price multiplied by seed yield. Predicted lint yield and seed yield values were a function of the management decision.

In calculating the corresponding total costs, the cost of irrigation water application was allocated per acre-inch, whereas the cost of phosphorus applied was assessed per pound per acre. Turnout (e.g. the percentage of clean marketable lint), variety, and phosphorus application method were also incorporated in the hedonic profit equation as variable costs per acre. For the purposes of the study, fixed costs included land, machinery, chemical, labor, and per acre harvesting costs.

The cost per acre-inch of water applied was calculated as the summation of a pumping cost to capture the cost of electricity and a machinery cost to account for maintenance, lube, and repair of irrigation equipment. Representative values of 200 feet and 16.5 PSI were assumed for pumping lift and pumping pressure, respectively (High Plains Underground Water District, 1998). The cost of electricity was set at $.082/KWH, which is reflective of the current (November 2000) price in the Texas High Plains. The variable cost of phosphorus fertilizer was set at $0.08/pound.

Cotton seed (e.g. variety) costs were calculated on the basis of dealer quotes. A seeding rate of 15 pounds per acre was assumed to calculate the cost of planting a given cotton seed variety. At this seeding rate, the variable retail costs for the Paymaster, All-Tex, and AFD certified varieties was $9.53/acre, $7.95/acre, and $8.85/acre, respectively. The cost of applying either HOL 101 or HOL 338 was $7.50/acre.

The cost estimates for cotton ginning and the different fertilizer application methods were taken from the 1998 Texas Custom Rates Statistics compiled by the Texas Agricultural Statistics Service (TASS). TASS estimated the cost of hiring a custom applicator to make one pre-plant or side-dress fertilizer application at $6.00/acre. Since the side-dress method requires three applications per cropping season, it involved a total application cost of $18.00/acre. The cost of applying phosphorus fertilizer through fertigation was allocated as a rental cost for a 1000-gallon tank and an injection pump, the additional equipment necessary for a typical farming operation to use fertigation. The estimated cost of renting a tank and an injection pump totaled to $15/ton of phosphorus or $.0075/pound. The ginning cost quoted in the custom rate statistics was $2.25/cwt per module. The original module weight was determined by dividing the predicted lint yields by the predicted turnout.

Scenarios for the Economic Analysis

In an analysis of the effect of market price information on the cotton industry, Ethridge and Hudson (1998) found that cotton producers possessing limited information about the prevailing premiums and discounts for quality differentials were more likely to make incorrect decisions. Two scenarios were constructed in this study to evaluate if the estimated production/quality response models together with Texas Tech University DPES premium/discount estimates could be used to improve the profitability of irrigated cotton production systems on the Texas High Plains.

The first scenario, imposing hedonic considerations, evaluated profitability and variation of profit under the assumption that the producer took lint quality into consideration when making input use decisions. The second scenario, involving non-hedonic profit-maximization, assumed that a producer selected input use levels in the absence of information about lint quality differentials. Under the hedonic scenario, yield, quality and turnout predictions from the estimated models were precise, and the prices and premium/discount schedules used to make the production factor decisions were fully realized. The result was 86 profit levels for each variety, which reflected the empirical probability distribution of maximum profits across the spectrum of weather observed in the region for a producer that considered cotton quality as a decision criterion. Under the non-hedonic scenario, yield, quality and turnout predictions from the estimated models were based upon input usage levels determined by a producer who adopted a market price estimate for planning purposes. The market price estimate utilized for this scenario represented an average of the market prices received from 1994-1999 for cotton in the Texas High Plains. The market price used to make production decisions was not fully realized. The producer instead received a price that incorporated adjustments based upon cotton quality premiums and discounts. The result was 86 profit levels for each variety, which reflected the empirical probability distribution of maximum profits across the spectrum of weather observed in the region for a producer that did not consider cotton quality as a decision criterion

Under both scenarios, the producer was assumed to have imperfect weather information, which complicated the selection of efficient input application rates. Because phosphorous fertilizer has to be applied during the first two months of the season, the analysis assumed that the fertilizer application decision was based on average heat unit accumulation and rainfall amounts equal to half the difference between actual and average rainfall for all 86 observed rainfall values. Irrigation water is applied periodically throughout the growing season with producers attempting to avoid under-irrigating crops, if possible. Sometimes, however, irrigation proceeds rainfall, wasting some or all of the water applied. With this in mind, the analysis assumed that when actual rainfall was below average, the irrigation decision was based on actual rainfall. However, when actual rainfall was above average, the irrigation decision was based on rainfall conditions equal to three fourths of the difference between the actual rainfall and the average of the 86 rainfall values in the analysis. It was also assumed that the irrigation decision was based on heat unit accumulation conditions equal to half the difference between the actual and the average heat unit accumulation. The profits were calculated using the hedonic equation under the 86 actual rainfall and heat unit accumulation values available.

Results and Discussion

Function Estimation

Denning et al. (2000) report the model parameters and related statistics for the six estimated functions utilized in this study. The coefficients of multiple determination (R^2) for the estimated lint yield, seed yield, and turnout models were 0.707, 0.702, and 0.421, respectively. These indicate that 70.7% of the variation in lint yield, 70.2 % of the variation in seed yield, and 42.1% of the variation in turnout observed in the data were explained by the corresponding models. The final lint yield model includes second-degree polynomial specifications with respect to irrigation water and phosphorus, indicating a non-linear lint yield response to these two inputs. The interaction term between water and phosphorus being positive and statistically significant indicates that a higher level of water (phosphorus) use increases the marginal physical productivity of (i.e. the rate of response to) additional phosphorus (water) application. Both weather variables (heat units and rainfall) are also statistically significant, as well as most variety intercept shifters. The choice of variety sometimes affects the rate of lint yield response to additional irrigation water and/or phosphorus application. Further, in certain cases, the impact of the phosphorus application method on lint yield levels is different depending on the variety. The seed yield model is fairly similar to the lint yield model, which is expected given the biological relationship between these two variables.

The R^2 values for the estimated micronaire, staple, and strength models were 0.353, 0.430, and 0.444, respectively, indicating that 35.3% of the variation in micronaire, 43% of the variation in staple, and 44.4% of the variation observed in the strength data were explained by the corresponding models. All three models contain statistically significant variety intercept shifters and interaction terms. The final micronaire model includes third-degree polynomial specifications with respect to water and phosphorous, while the final strength model contains second- and third-degree polynomial specifications with respect to phosphorous and water, respectively. Water appears to have a linear effect on staple, but phosphorous application does not seem to affect this quality characteristic. In short, water and phosphorous have a statistically significant effect on quality. Further, all quality models indicate statistically significant effects of the weather variables and interactions of these variables with water and phosphorous.

Graphical Response Surfaces for Lint Yield

Figure 3 shows the production response surface predicted by the lint yield equation for Paymaster HS 26 and Paymaster Tejas (the baseline varieties), assuming the Lubbock, Texas long-term average May-to-September heat unit accumulation and rainfall values of 1275C and 9.5 inches. At a low irrigation water use level of 5 acre-inches, the lint yield response to additional phosphorous application (0 to 70 pounds/acre) is positive and substantial (600 to 900 pounds/acre). The response is even more pronounced at higher irrigation water use levels (from 800 to 1300 pounds/acre at 14 acre-inches). The general pattern under the long-term average weather scenario is one of substantial lint yield response to both irrigation water and phosphorous fertilizer application at all input use levels.

The lint yield response surfaces for Paymaster HS 200, Delta Pine 2156, HOL 101, All-Tex Atlas, AFD Explorer, AFD Rocket, All-Tex Toppick, and All-Tex Xpress followed a pattern similar to the baseline varieties, with the exception of HOL 338. HOL 338 presented a more pronounced lint yield response to phosphorous application, especially at low irrigation water use levels. Across varieties, the model predicts maximum lint yields ranging from 1289 (Paymaster HS 200) to 1376 pounds/acre (HOL 338). The maximum lint yield values always occur at the highest irrigation water and phosphorous application rates evaluated.

Extreme weather scenarios substantially shift the predicted lint yield response surfaces. Under high heat units (1500C) and low rainfall (5 inches), i.e. an extremely hot and dry year, there is little lint yield response to phosphorous application at the lower irrigation water-use levels. As expected, lint yields respond strongly to additional irrigation, regardless of the amount of phosphorous applied. HOL 338 presents the most favorable lint yield response to phosphorous application at all water use levels. The model predicts maximum lint yields ranging from 961 to 1050 pounds/acre. Maximum lint yields occur at the highest irrigation water level, but at intermediate phosphorous application rates (50-60 pounds/acre).

With a heat unit accumulation of 1050C and 15 inches of rainfall (i.e. a year with mild summer temperatures and high precipitation), the model predicts a marginal lint yield response to irrigation water at the lowest phosphorous fertilizer application. Yield response to irrigation water increases as additional phosphorous is applied. Lint yields respond strongly to additional phosphorous. The general pattern under this scenario is one of substantial lint yield response to phosphorous application but relatively low to moderate response to irrigation water. HOL 338 shows the strongest lint yield response to phosphorous application at any water use level. The model predicts maximum lint yields occurring at the highest irrigation water and phosphorous application rates evaluated.

The weather scenario pairing low heat units (1050C) and rainfall (5 inches) is the worst for cotton lint yields in the Texas High Plains. Under this scenario, little or no lint yield response to phosphorous application is predicted at the lower irrigation water-use levels. At the highest water use, additional phosphorous application causes a moderate increase in cotton lint yields. As in the previous scenarios, HOL 338 presents the strongest lint yield response to phosphorous application at any water use level. The model predicts maximum lint yields at the highest irrigation water and at intermediate phosphorous application rates. The best-case scenario for cotton lint yields in the Texas High Plains is the highest heat unit accumulation (1500C) and rainfall (15 inches). As in the average weather scenario, the model predicts substantial lint yield responses to both irrigation water and phosphorous fertilizer application. However, the yield responses are more pronounced than in the average weather scenario at all input use levels.

Contour Maps for Micronaire

Figure 4 is a contour map describing the micronaire response of two baseline varieties, Paymaster HS 26 and AFD Explorer, to irrigation water and phosphorus fertilizer application under a long-term average heat unit accumulation scenario (1275C). The micronaire ranges used in this contour map are based on the ranges for micronaire premium and discounts in Nelson et al. (2000). Nelson et al. (2000) estimate that micronaire values between 3.5 and 5 did not result in a price discount for West Texas cotton in the 1998/99 and 1999/2000 crops. Micronaire values under 3.0 or over 5.0 produced substantial discounts of 3 cents/pound in 1999/2000 and nearly 4 cents/pound in the 1998/99 season. The micronaire response surfaces of the other varieties follow the same general pattern of Figure 4.

Under long-term average heat unit accumulation, the predicted micronaire response surfaces suggest that low micronaire values (below 3.5) would occur at high levels of irrigation water use, regardless of the amount of phosphorous applied. However, at 70 pounds of phosphorous per acre, Paymaster HS 26, Delta Pine 2156, Paymaster Tejas, HOL 338, All-Tex Atlas, and AFD Explorer tolerated up to 12 acre-inches of irrigation water before showing micronaire values below 3.5. At the lint yield maximizing levels of 70 pounds of phosphorous and 14 acre-inches of water, the predicted micronaire values range from 2.38 to 3.07, depending on the variety. The highest micronaire values occurred at low irrigation water and high phosphorous, but never exceeded 5.0 under this average heat unit scenario.

Lower heat units (1050C) cause substantial changes in the micronaire response surfaces for all varieties. For instance, at 70 pounds of phosphorous per acre, Paymaster HS 200 and All-Tex Toppick start showing micronaire values below 3.5 after only 8 acre-inches of irrigation water use. The remaining varieties begin showing micronaire values under 3.5 after 9 acre-inches of water. At 70 pounds of phosphorous and 14 acre-inches of water, all varieties show predicted micronaire values of under 2.1, implying that in low-temperature years West Texas cotton producers could be subject to substantial discounts for low micronaire when applying high amounts of irrigation water and phosphorous fertilizer. In this scenario, the highest micronaire values occurred at low irrigation water use, but never exceeded 5.0.

A higher heat unit accumulation (1500C) causes favorable changes in the micronaire response surfaces for most varieties. Paymaster HS 26, HOL 101, All-Tex Atlas, AFD Rocket, and All-Tex Xpress never show micronaire values outside the desirable 3.5-5.0 range, as long as irrigation water and phosphorous application is kept within the limits evaluated in the study. Delta Pine 2156, Paymaster Tejas, HOL 338, and AFD Explorer present micronaire values above 5, but only at high phosphorous application combined with low irrigation water use. Paymaster HS 200 and All-Tex Toppick, which showed low to very low micronaire values at moderate to high irrigation water levels in the low and average heat unit scenarios still present relatively low micronaire readings at some water-phosphorous combinations.

Contour Maps for Strength

Nelson et al. (2000) estimate that strength values between 24 and 25 grams/tex did not result in a price discount for West Texas cotton in the 1998/99 and 1999/2000 crops. Strength values under 23 grams/tex produced substantial discounts of 1 to 2 cents/lb, while strength readings over 27 grams/tex resulted in premiums of 0.9 to 1.4 cents/lb, depending on the cropping season. Figure 5 shows the contour map predicted by the fiber strength equation for Paymaster HS 26, under the average weather scenario of 1275C accumulated heat units and 9.5 inches of rainfall. In general, the lower strength values range from 23 to 27 grams/tex, while the highest are between 30 and 35 grams/tex, depending on the variety. The lowest range of strength values occurs at the highest irrigation water use level evaluated, while the highest strength readings are predicted under the lowest water use. At either water use level, additional phosphorous only increases strength modestly by 1-2 grams/tex.

Low heat units (1050C) combined with high rainfall (15 inches) broadens the range of predicted fiber strengths from 15-21 grams/tex at high irrigation water and low phosphorous application rates to 34-39 grams/tex at low irrigation water and high phosphorous application rates, depending on the variety. High heat units (1500) combined with the same abundant amount of rainfall (15 inches) produces somewhat higher strength readings, within a wide range of 18-24 to 36-40 grams/tex, depending on the variety. In all three previously discussed weather scenarios, additional irrigation water decreased fiber strength considerably, while increased phosphorous fertilization only increased fiber strength moderately.

In a scenario of high heat units (1500C) and low rainfall (5 inches), most varieties present a very narrow range of strength values between 27 and 32 grams/tex across all phosphorous-water use combinations evaluated. Paymaster HS 200, Paymaster Tejas, and All-Tex Toppick generally show higher strength readings (between 30 and 35 grams/tex) implying that cotton producers growing any one of these varieties in West Texas would likely gain the highest possible premiums for fiber strength in hot and dry years, regardless of the amount of phosphorous fertilizer and irrigation water applied. Low heat units (1000C) combined with the same sparse amount of rainfall (5 inches) produced somewhat lower strength readings, within a range of 24 to 32 grams/tex for all varieties.
In short, the fiber strength model predicts that higher rainfall results in a broader range of fiber strength readings across the phosphorous-water use combinations evaluated. However, this broadening is more pronounced in the lower than in the upper bound of the range, implying that rainfall has a negative impact on fiber strength. Higher heat units on the other hand produce stronger cotton fiber at an average rate of approximately 0.5 grams/tex per 100 additional heat units.

Contour Maps for Staple Length

Nelson et al. (2000) estimate that staple length values between 1.06 and 1.16 inches did not result in a price discount for West Texas cotton in the 1998/1999 and the 1999/2000 cropping seasons. Staple length values under 1.03 resulted in significant price discounts, ranging from 1 to 11 cents per pound, depending on the season. Staple lengths in excess of 1.06 resulted in premiums, ranging from 1 to 5 cents per pound. Figure 6 is a contour map depicting staple response to irrigation water and phosphorus fertilizer application for variety Paymaster HS 26 under the long-term average weather scenario.

In this scenario, the lower staple length values predicted by the model range from 0.94 to 1.04 inches, whereas the highest staple length values oscillate from 1.04 to 1.12 inches, depending on the variety. Paymaster HS 200 and All-Tex Toppick show generally higher staple length readings, ranging from 1.08 to 1.17. In general, the lowest range of staple values occurs at the highest irrigation water use evaluated and at zero pounds of phosphorus fertilizer per acre, while the highest staple length measurements are associated with the lowest irrigation water use and the highest amount of phosphorus fertilization. For all varieties and water use levels, additional phosphorus fertilizer application only generates moderate increases in staple length, generally less than one-hundredth of an inch.

Low heat units (1050C) and high rainfall (15 inches) broadens the range of predicted staple length values from 0.80-0.97 inches at higher irrigation water use and low phosphorus fertilizer application levels to 1.06-1.20 inches at low irrigation water and high phosphorus fertilizer application rates, depending on the variety. High heat units (1500C) combined with above average rainfall (15 inches) produces somewhat lower staple length values, also within a wide range of 0.76-0.93 to 1.06-1.19 inches, depending on the variety. Under these first three weather scenarios, like in the case of fiber strength, the model predicts that additional irrigation water use substantially decreases staple length, while phosphorus fertilization only increases staple length marginally.

In a scenario of high heat units (1500C) and below average rainfall (5 inches), most varieties present a narrower range of staple length values, between 1.03 and 1.16 inches, across all phosphorus and irrigation water combinations evaluated. Paymaster HS 200 and All-Tex Toppick produce generally higher staple length readings between 1.09 and 1.24 inches. In general, the lower staple length values occur at the minimum irrigation water and phosphorus fertilizer application levels, whereas the highest values are at the maximum water and phosphorus application rates evaluated. Low heat units (1050C) combined with below average rainfall (5 inches) produce similar results and ranges, implying that for all varieties a producer would likely obtain the highest possible premiums for staple strength in a relatively dry year, regardless of the amount of irrigation water and phosphorus applied or the amount of accumulated heat units.

Economic Analyses

The estimated production response models showed clear agronomic tradeoffs between yields and quality. In all of the weather scenarios evaluated above, the variety and input use combination that maximized lint and seed yields was different from the combination that optimized the value (e.g. minimized the discount or maximized the premium received) of any particular quality attribute. These agronomic tradeoffs coupled with the interaction terms identified by the models confirmed the importance of conducting economic analyses of the impact of hedonic considerations on the profitability of irrigated cotton production in the Texas High Plains. Tables II and III contain the expected profit levels, standard deviations of profit, probability of obtaining negative net and gross profits, average phosphorus and irrigation water application rates, and lint price estimates for each variety across the 86 rainfall-heat unit combinations for the two price scenarios. The tables also provide an average of the previously listed results for all varieties, as well as the average of the best cross-variety combination for each observed weather scenario.

With hedonic considerations, 10 of the 11 varieties evaluated present higher 86-year average profits (cross-variety average of $8.2/acre profit increase) than under the non-hedonic profit maximization scenario. Profit variability is similar under both the hedonic and the non-hedonic scenarios, but the probability of negative profit decreases from 29.1% (non-hedonic) to 22.1% (hedonic). As expected, all varieties receive higher 86-year average premiums for cotton lint quality under the hedonic profit maximization scenario. Hedonic profit maximization slightly increases phosphorous fertilizer application by a cross-variety average of 4% (or 2.7lbs/acre), and substantially raises irrigation water use by an average of 30% (or 2.1 acre-inches) across varieties.

The results of the economic analyses suggest that variety selection is important, given the substantial differences in the maximum profit that can be obtained when using the different varieties. Furthermore, the profit-maximizing variety is not the same in the two scenarios. Under the non-hedonic scenario, All-Tex Xpress results in the highest average profits over the 86 rainfall-heat unit combinations used in the analysis. Under the condition of selecting the one variety that performs best on average across all of the rainfall-heat unit combinations in the analysis, hedonic profit maximization allows for considerably higher profits and lower profit variability than non-hedonic profit maximization. Specifically, variety HOL 338 would be selected instead of All-Tex Xpress, increasing average profits from $150.0/acre to 171.7/acre, slightly reducing the year-to-year variability in profits from $235.4/acre to $232.7/acre, and substantially lowering the probability of negative profits from 32.6 to 22.1%. The difference in this case is that the lint quality premiums received when growing HOL 338 can be increased by 2.7cents/lb through input-use decisions that are based on hedonic profit maximization, while they can only be increased by 0.2cents/lb with All-Tex Xpress.

In short, under the current situation of non-hedonic decision-making, a profit-maximizing producer would always plant variety All-Tex Xpress obtaining average profits of $150/acre with a standard deviation of $235.4/acre and a 32.6% probability of obtaining negative profits during any given year due to weather uncertainty. Under hedonic decision-making, a profit-maximizing producer would always grow HOL 338 obtaining average profits of $171.7/acre with a standard deviation of $232.7/acre and a 22% probability of negative profits.

Two final comments about the previously discussed results are in order. First, the relatively high average per-acre profit levels reported are due to the cotton lint base price of 65 cents per pound used in the analysis, which is the average of the annual DPES base price estimates for the 1995 to 1999 marketing seasons. The above-average yields (600-1200lbs/acre) obtained in the experiments providing the data used to estimate the production response functions also contributed to the high profit levels predicted by the models. Nevertheless, the differences in the estimated profits across the two main scenarios evaluated should be generally indicative of what could happen at other price and yield levels. Second, the measures of profit variability (e.g. the probability of negative profits and of not covering total variable costs) are only in relation to yield variability caused by weather uncertainty. These measures underestimate the actual level of profit variation experienced by cotton producers, which is exacerbated by other sources of yield variability and price uncertainty.

Conclusions and Recommendations

Researchers and producers commonly accept that variety and weather affect cotton quality. A main conclusion of this research is that input use, more specifically irrigation water/nitrogen and phosphorous fertilizer use, have a substantial, statistically significant impact on lint quality. Also, the magnitude of the effect of changes in input use rates on quality is noticeably different depending on the variety and prevailing weather. The relationship between the predicted effect of variety, water/nitrogen and phosphorous fertilizer use, and the prevailing weather on lint quality is large enough to trigger considerable premiums and discounts under the current cotton pricing system. Substantial agronomic tradeoffs between lint yields and quality are identified as well.

Overall, consideration of quality when making variety and input-use decisions has the potential to substantially increase profitability and reduce profit variation for irrigated cotton producers on the Texas High Plains. Computer savvy extension agents and producers could couple the models and procedures advanced in this study with relevant cost data and information about cotton prices, including the premiums and discounts being paid for the three quality attributes, to make better variety selection and input use decisions. Better decision-making ability will improve profitability of farm operations. Availability of precise, up-to-date estimates of the quality premiums and discounts, implicit in the observed market lint prices, would be critical for these purposes.

A final note of caution about the production response models estimated in this study. Though statistically sound, the models are based on three years of experimental data from Lubbock County. The yield and quality predictions from these models are imperfect due to the usual “random” error, e.g. the effect of factors not included in the models. When applied in farm management decisions, the predictions would also be subject to “extrapolation” error caused by any major difference between the experimental site management and the farm site management. Re-estimating the models on the basis of an expanded data set that includes future-year observations from other Texas High Plains cotton-farming areas could reduce this extrapolation error. Similar models could be estimated and eventually used for farm-level decision making in the other three major cotton-producing areas of the United States.

Acknowledgements

This research was supported by CSREES/USDA, through the International Cotton Research Center. The authors acknowledge the valuable comments and suggestions of Marty Middleton and Drs. Don Ethridge, Dean Ethridge, Eduardo Segarra, and Norman Hopper.

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Table I: Annual average DPES lint base price and quality premium/discount estimates (1994/1995 to 1998/1999).

		Year					
		1995	1996	1997	1998	1999	Average
Base Price		71.8	75.9	64.4	58	51.1	64.25
Micronaire	2.4 or Below			-1144	-520		-832.0
	2.5 - 2.6		-819	-969	-433	-849	-767.5
	2.7 - 2.9	-323	-565	-704	-304	-612	-501.6
	3.0 - 3.2	-197	-315	-432	-177	-370	-298.2
	3.3 - 3.4	-114	-157	-252	-96	-210	-165.8
	3.5 - 4.9	0	0	0	0	0	0.0
	5.0 - 5.2	-164		-375	-207	-371	-279.3
	5.3 or Above			-540	-294	-527	-453.7
Strength	18 or Below			-63			-63.0
	19			-53			-53.0
	20	-35		-44			-39.5
	21	-27		-34			-30.5
	22	-20	-34	-24	-64	191	9.8
	23	-12	-20	-15	-36	-106	-37.8
	24 & 25	0	0	0	0	0	0.0
	26	12	20	15	28	78	30.6
	27	20	34	24	43	113	46.8
	28	27	48	34	54	135	59.6
	29	35	61	44	62	143	69.0
	30	43	75	54	66	143	76.2
	31or Above	51	89	64	67	143	82.8
Staple	29	-313		-576	-297	-1070	-564.0
	30	-230	-274	-421	-220	-797	-388.4
	31	-157	-181	-284	-152	-548	-264.4
	32	-94	-104	-168	-92	-329	-157.4
	33	-42	-43	-73	-41	-144	-68.6
	34	71.8	75.9	64.4	58	51.1	64.3
	35	72	76	50	32	101	66.2
	36	72	76	76	54	155	86.6
	37			79	66	162	102.3
	38			79	69		74.0

* Staple length premiums and discounts are taken at a base color grade of 41.
*All premiums and discounts are given in points per pound.
100 basis points = 1 cent.

Table II: Non-hedonic profit maximization scenario.

Variety	Expected Profit ($/acre) Average	Std Dev	Probability of Negative Net Profit	Probability of Negative Gross Profit	Phosphorus (lbs/acre) Average	Minimum	Maximum	Irrigation Water (acre-inches) Average	Minimum	Maximum	Price ($/lb) Average
Paymaster HS 26	84.7	230.4	38.37%	19.77%	67	23	73	7	3	11	0.69
Paymaster HS 200	118.1	258.5	32.56%	18.60%	71	39	73	6	3	10	0.71
Delta Pine 2156	117.7	245.8	29.07%	16.28%	71	37	73	9	3	13	0.70
Paymaster Tejas	92.0	234.5	36.05%	20.93%	67	23	73	7	3	11	0.70
HOL 101	105.8	258.1	32.56%	17.44%	71	37	73	7	3	11	0.71
HOL 338	146.3	244.6	30.23%	11.63%	73	71	73	6.5	3	10	0.69
All-Tex Atlas	102.9	246.6	31.40%	18.60%	70	30	73	8.7	3	13	0.71
AFD Explorer	102.8	247.0	31.40%	17.44%	70	32	73	8.7	3	13	0.71
AFD Rocket	102.5	251.9	31.40%	18.60%	71	36	73	8.7	3	13	0.72
All-Tex Toppick	121.5	244.6	34.88%	5.81%	64	20	73	6.5	3	11	0.73
All-Tex Xpress	150.0	235.4	32.56%	1.16%	66	22	73	6.7	3	11	0.71
All Varieties	113.1	245.2	32.77%	15.11%	69.2	33.6	73	7.4	3	11.5	0.71
Cross Variety	166	230	29.07%	1.16%	67.6	22	73	7.4	3	13	0.71

* Price is the 1995-1999 average DPES lint base price estimates plus any earned quality premium or discount.
* Best varieties assumes that the variety that performs the best under the weather conditions observed during each of the 86 years in the analysis is selected for planting during that year.

Table III: Hedonic profit maximization scenario.

Variety	Expected Profit ($/acre) Average	Std Dev	Probability of Negative Net Profit	Probability of Negative Gross Profit	Phosphorus (lbs/acre) Average	Minimum	Maximum	Irrigation Water (acre-inches) Average	Minimum	Maximum	Price ($/lb) Average
Paymaster HS 26	84.5	233.6	33.72%	18.60%	70	30	73	8.7	3	14	0.69
Paymaster HS 200	129.8	258.3	30.23%	16.28%	73	73	73	8.8	3	13	0.73
Delta Pine 2156	131.4	235.0	23.26%	11.63%	73	72	73	11	3	14	0.71
Paymaster Tejas	93.1	243.6	32.56%	17.44%	72	29	73	9	3	14	0.70
HOL 101	118.1	254.5	29.07%	15.12%	73	71	73	9.7	3	14	0.72
HOL 338	171.7	232.7	22.09%	8.14%	73	73	73	10	3	14	0.71
All-Tex Atlas	109.7	243.4	29.07%	15.12%	73	56	73	10.5	3	14	0.71
AFD Explorer	112.9	241.3	29.07%	15.12%	73	56	73	10.6	3	14	0.71
AFD Rocket	112.2	244.4	29.07%	12.79%	73	59	73	10.6	3	14	0.72
All-Tex Toppick	120.4	251.0	31.40%	16.28%	70	34	73	8.4	3	13	0.73
All-Tex Xpress	151.0	242.8	25.58%	16.28%	71	36	73	9	3	14	0.72
All Varieties	121.3	243.7	28.65%	14.80%	72.2	53.5	73.0	9.7	3	13.8	0.71
Cross Variety	181	227	22.09%	8.14%	70.7	36	73	10.1	3	14	0.72

* Price is the 1995-1999 average DPES lint base price estimates plus any earned quality premium or discount.
* Best varieties assumes that the variety that performs the best under the weather conditions observed during each of the 86 years in the analysis is selected for planting during that year.

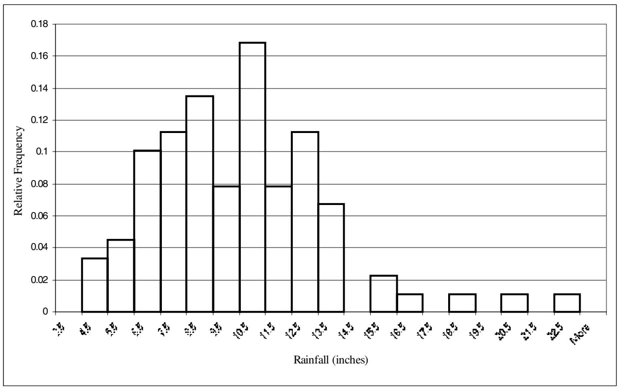


Figure 1: Relative frequency distribution for May-to-September rainfall in Lubbock County (1911-1999).

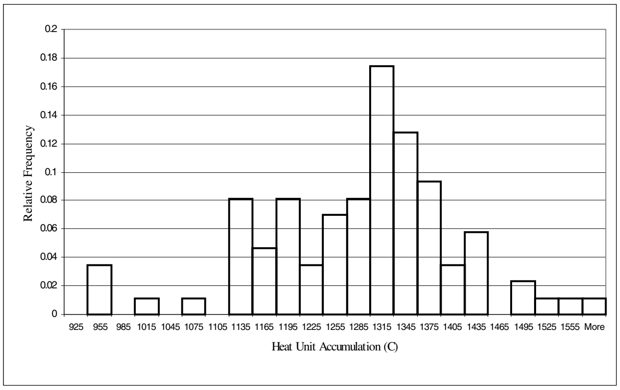


Figure 2: Relative frequency distribution for May-to-September heat unit accumulation based on temperature readings at the Lubbock International Airport (1914-1999).

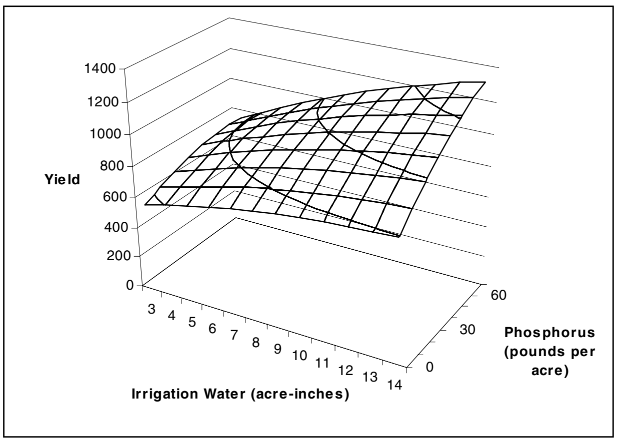
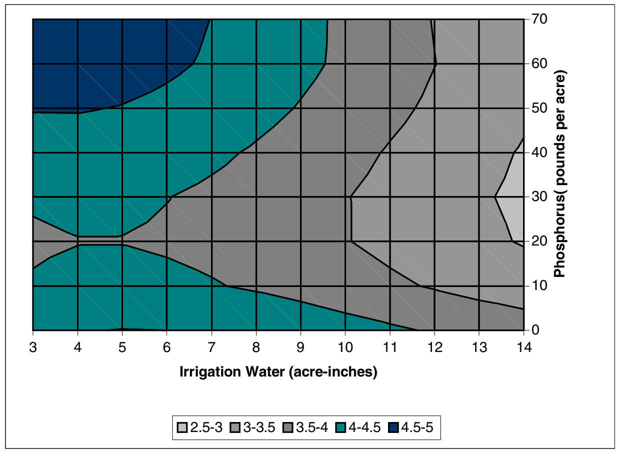
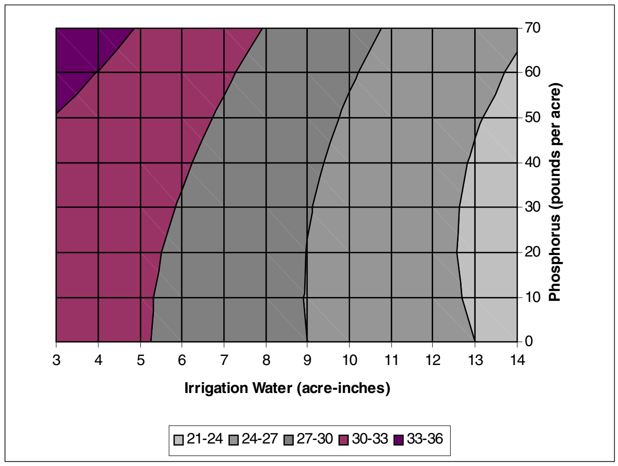


Figure 3: Lint yield response surface for variety Paymaster HS 26 under the long-term average weather values for Lubbock, TX.



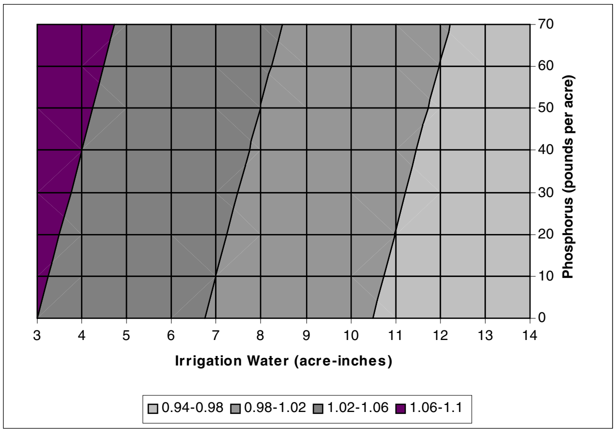
Note: Darker color shades represent higher micronaire ranges.

Figure 4: Contour map for micronaire response of variety Paymaster HS 26 and AFD Explorer under the Lubbock, TX long-term average heat unit accumulation of 1275C.



Note: Darker color shades indicate higher fiber strength ranges.

Figure 5: Contour map for fiber strength response of variety Paymaster HS 26 under the long-term average heat unit and rainfall values of Lubbock, TX.



Note: Darker color shades indicate higher staple length ranges.

Figure 6: Contour map for staple length response of variety Paymaster HS 26 under the long-term average heat unit and rainfall values of Lubbock, TX.