Optimal Plant Population for Ultra-Narrow-Row Cotton Production as Influenced by Lint and Transgenic Seed Prices

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Abstract:

Farmers are concerned about the high costs of transgenic seed and technology fees associated with the large plant population densities recommended for ultra-narrow row cotton. This study evaluated the effects of alternative plant population density decision criteria on net revenues under different lint price and transgenic seed cost scenarios. Results indicate that farmers may be able to maximize profits by seeding for a target plant population density of approximately 15.5 plants m^{-2}.

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Optimal Plant Population for Ultra-Narrow-Row Cotton Production as Influenced by Lint and Transgenic Seed Prices

Cotton growers are concerned about the impact of low lint prices and rising production costs on the profitability of cotton production (National Cotton Council Staff). Cotton has traditionally been produced in 97 or 102 cm rows and requires a large investment in equipment and extensive use of fertilizers, insecticides, herbicides, growth regulators, and harvest aids. In addition, cotton produced using wide row-spacing and conventional tillage leaves minimal crop residue on the soil surface. The estimated average crop residue remaining after planting is 3% for cotton compared to 29% for corn (USDA-ERS). The absence of crop residue with wide-row production may exacerbate soil erosion problems and the runoff of chemicals and nutrients applied to cotton (Hyberg).

Because of concerns about the deterioration of cotton profit margins and the environmental impacts of row-crop cotton production, farmers have increased their interest in ultra-narrow-row cotton (UNRC) technology (Gwathmey and Hayes). The production system referred to as UNRC has been defined in terms of row spacing of less than 25 cm (Atwell), but some contemporary UNRC row spacings include 19, 25, and 38 cm (Parvin et al.). A common characteristic of UNRC is the use of very high plant population densities (PPDs), relative to wide-row cotton (Delaney et al.). Recommended PPDs for UNRC range from 19.8 to 49.4 plants m^{-2} (Delaney et al.). By comparison, typical PPDs for wide-row cotton range from 7.4 to 14.8 plants m^{-2}. A major reason for relatively high PPDs revolves around limitations of available planting and harvesting equipment for UNRC. Farmers typically use a grain drill rather than a row planter or precision planter to seed UNRC. A finger stripper that has a single wide-swath header is used instead of a spindle picker to harvest UNRC. High PPDs are used in UNRC production to compensate for imprecise seed placement with a drill and to facilitate efficient machine harvesting with a finger stripper.

Reported advantages of UNRC include lower machinery and labor costs and higher yields (Parvin; Jost and Cothren). Brown et al. (1998) evaluated costs for UNRC and wide-row cotton on five farms participating in industry field tests in 1996. They found that the fixed costs of production for UNRC were lower than for picker cotton. An important factor in the lower fixed costs with UNRC is the considerably lower ownership and operating costs for a finger stripper when compared with a spindle picker.

Impeding the potential profitability of UNRC is the substantially higher seeding costs associated with the much larger PPDs used in UNRC (Parvin et al.). Brown et al. (1998) found that all variable costs of production averaged \$42 ha^{-1} higher for UNRC cotton, of which seed costs averaged \$39 ha^{-1} higher. High seed costs, especially with the use of more expensive transgenic varieties, have impeded the adoption of the UNRC production system. Over 90% of cotton acreage in Tennessee and 77% of all U.S. cotton acreage is planted using transgenic varieties (USDA-AMS). Another potential drawback of UNRC is finger-stripping cotton may result in more leaf and bark content in the lint than spindle picking, because more of these plant parts are harvested by the finger stripper, and they are not completely removed during lint cleaning. Valco et al. documented the greater frequency of bark content in finger-stripped UNRC relative to spindle-picked cotton across 15 locations and 2 years. Higher leaf and bark in lint may result in larger price discounts for UNRC relative to spindle-picked cotton.

Because of high seeding costs with UNRC relative to wide-row cotton, producers need information about net revenue tradeoffs associated with the PPD decision to evaluate the feasibility of the UNRC production system. The optimal seeding rate for UNRC is influenced by the relationship between seeding rate and PPD, lint yield and quality responses to PPD, lint prices, price adjustments for quality, seed costs, and harvest efficiency. The objective of this study is to evaluate the effects of alternative plant population density decision criteria on UNRC net revenues for various lint price and transgenic variety seed cost scenarios.

Analytical Framework

A combination of partial budgeting and marginal analysis techniques were used to evaluate the PPD decision for UNRC. The following partial budgeting equation was used to estimate net revenues for UNRC:

$$(1) \qquad NR = [P^b + PD(PPD)] \times Y(PPD) - PPD \div PPS^{Farmer} \div SEED \times P^s - FEE^{Policy},$$

where PD(PPD) is lint price difference ($\$\ kg^{-1}$) and Y(PPD) is lint yield ($kg\ ha^{-1}$) both as a function of PPD (plants m^{-1}), P^b is the base quality price for lint ($\$\ kg^{-1}$), PPS^{Farmer} is the expected plant population survival as a proportion of the seeding rate that is used by a farmer to determine the seed planting rate, SEED is the number of seeds kg^{-1} for the variety planted, P^s is the price of seed ($\$\ kg^{-1}$) for a transgenic cultivar, and FEE^{Policy} is the technology fee ($\$\ ha^{-1}$) charged for a transgenic cultivar under alternative pricing policies. Equation (1) was used to evaluate UNRC PPD net revenue tradeoffs under alternative PPD decision criteria and alternative transgenic variety seed pricing policy scenarios.

Because of the wide range of PPDs that have been recommended for UNRC production (Delaney et al.), equation (1) was used to evaluate UNRC net revenues for three PPD decision criteria: 1) an Agricultural Extension Service recommended PPD for UNRC of 24.7 plants m^{-2} (247,100 plants ha^{-1})(University of Georgia), 2) an “agronomic minimum” PPD that may be needed to facilitate efficient harvest with a finger stripper, and 3) the PPD required to maximize net revenues using the relationship between expected lint and seed prices. Farmers may encounter agronomic constraints that limit the effectiveness of planting UNRC at lower PPDs. The "agronomic minimum" is a possible lower limit of PPD that is based on several agronomic constraints: 1) the ability of farmers to plant to a minimum stand with available UNRC planter or drill technology, 2) the need to avoid large skips in the stand that can cause weed and harvest problems, 3) the ability to control weed escapes with available herbicide technology, and 4) the need to suppress large cotton plant branches that may interfere with stripper harvesting. The "agronomic minimum" PPD in UNRC was established to be about 15.5 plants m^{-2} (155,000 plants ha^{-1}) based on unpublished UNRC data that relates cotton plant branch length with PPD (C.O. Gwathmey, Personal Communication, 2 Apr. 2003). The data show that branch size increases dramatically for populations less than 15.5 plants m^{-2} but remain relatively constant for populations greater than 15.5 plants m^{-2}. The prevalence of more large plant branches and weed escapes at low PPDs may reduce finger stripper efficiency and increase harvest costs in large field situations.

The pricing of cotton varieties changed with the introduction of transgenic cotton in the mid 1990s. The pricing policies used by transgenic seed providers have a potentially large impact on the optimal PPD and seed cost for the UNRC production system. Monsanto, which licenses glyphosate-tolerant (Roundup Ready) and Bt (Bollgard) technologies through different seed companies, initially charged a farmer a fixed technology fee (\$ ha^{-1}) that was in addition to the variety seed cost (\$ kg^{-1}) that is charged by the seed company. For example, the glyphosate-tolerant variety PM 1220 RR had a suggested retail price of \$43.95 bag^{-1} that is charged by the seed company and a \$22.24 ha^{-1} technology fee (TF) that is charged by Monsanto (Monsanto Corporation). Farmers licensing the technology must provide documentation of area planted for the purpose of billing technology fees.

Starting in 1998 Monsanto modified its technology fee policy for wide-row cotton and developed a separate policy for UNRC cotton (Monsanto Corporation). For wide-row cotton, the technology fee is calculated using what is called the seed drop rate (SDR) and the seed variety category (SVC). Monsanto defines the SDR as the number of seed dropped from the planter to achieve a final PPD. The SDR varies by production region. For example the SDR is 154,438 ha^{-1} for West Tennessee compared with 128,492 ha^{-1} for Georgia (Monsanto Corporation). According to Monsanto, the SDR is based on seeding rate and PPD data compiled from state universities, crop consultants, seed companies, and others, and is supposed to represent common planting practices for different production areas across the U.S. Cotton Belt. SVC defines the seed size category for a variety. Thus, for a farmer in West Tennessee, the technology fee (FEE) for a 22.64 kg bag of PM 1220 RR with a SVC classification of 9,261 seeds kg^{-1} is calculated as follows:

(2) $$\text{FEE} = \frac{\text{SVC} \times 22.64}{\text{SDR}} \times \text{TF} = \frac{9{,}261 \times 22.64}{154{,}438} \times \$22.24 = \$30.24\ \text{bag}^{-1} \div 22.64 = \$1.33\ \text{kg}^{-1}.$$

The revised technology fee policy converts the per hectare technology fee to a per bag or kilogram basis. Under this policy, a farmer who plants exactly 154,438 seeds ha^{-1} pays a technology fee of \$22.24 ha^{-1} while a farmer who plants less than 154,438 seeds ha^{-1} pays a technology fee of less than \$22.24 ha^{-1}. Under this system there is an incentive for farmers to reduce the technology fee by using a seed planting rate that is less than the SDR.

Under Monsanto's UNRC exception policy, farmers are exempted from paying a per bag technology fee and instead pay the per hectare technology fee. Farmers are required to grow at least 20.2 ha of UNRC to be eligible for the exception. The UNRC SDR is determined by estimating the PPD in the field after planting and dividing that PPD by a plant population survival proportion of 0.80. The UNRC SDR is used to calculate the number of bags excepted from the per bag fee. Any bags used beyond those excepted are charged technology fees on a per bag basis using the wide-row pricing policy discussed previously. For example, farmers who use a lower plant population survival proportion to determine their seeding rate rather than the 0.80 used by Monsanto, pay additional technology fees above the base per hectare rate.

Based on the previous discussion, alternative transgenic cotton variety pricing policies and their impact on the optimal PPD, seed costs, technology fees, and net revenues for the UNRC planting decision were evaluated using equation (1):

$$\text{(3)} \qquad FEE^{\text{Wide - Row}} = \frac{SVC}{SDR^{\text{Policy}}} \times TF\,,$$

$$\text{(4)} \qquad FEE^{\text{UNRC}} = TF + \left[\left(\frac{PPD}{PPS^{\text{Farmer}} - PPS^{\text{Monsanto}}}\right) \div 2 \times SVC\right] \times FEE^{\text{Wide - Row}}\,,$$

and

$$\text{(5)} \qquad FEE^{\text{UNRCNL}} = TF\,.$$

Two seed drop rate policies (SDR^{Policy}) were evaluated using the wide-row technology fee policy ($FEE^{Wide\text{-}Row}$) represented in equation (3). The first is a SDR=154,438 plants ha^{-1} which is the current wide-row SDR for West Tennessee. The second is a SDR=308,875 plants ha^{-1} which is consistent with an Agricultural Extension Service recommended PPD for UNRC of 247,100 plants ha^{-1} assuming a PPS of 0.80 (University of Georgia). Equation (4) models the current Monsanto UNRC exception policy (FEE^{UNRC}). PPS^{Farmer} represents the expected plant population survival proportion used by a farmer to determine their seeding rate. $PPS^{Monsanto}$ is the 0.80 plant population survival proportion used by Monsanto to determine how many bags are eligible for the UNRC exception. Equation (5) models a UNRC exception where the number of bags eligible for the exception is not limited and the technology fee is calculated based on area planted only (FEE^{UNRCNL}).

Data and Methods

Lint Yields. Yield response as a function of PPD [Y(PPD)] for equation (1) was estimated using the lint yield and PPD data from field experiments conducted in 1997 through 2000 at the University of Tennessee Agricultural Experiment Station at Milan, TN. Cotton was planted in 25.4 cm rows in each year of the experiment. Two similar transgenic varieties, PM 1220 RR and PM 1218 BR, were used in the experiment. At the 1- to 2-leaf growth stage, plots were hand thinned to four target PPD levels in 1997 and 1998 and five target PPD levels in 1999 and 2000. Plant population density treatments were arranged in a randomized complete block design with four or five replications. Average PPDs established by the treatment levels were 6.7, 11.6, 19.9, 28.8, and 38.2 plants m^{-2}. Plot assignments of treatments were re-randomized as the experiment was moved to a new field site in each year of the study.

Plots were harvested once with a finger stripper in each year of the experiment. Seedcotton harvested from each plot was weighed, and a grab sample was taken from each plot, weighed, and air-dried before ginning. Seedcotton samples were ginned with a 20-saw gin equipped with a stick machine, dual incline cleaners, and two lint cleaners at the West Tennessee Experiment Station, Jackson TN. Lint was weighed and a sub-sample of lint was analyzed by high volume instrument (HVI) testing and hand-classing procedures at the USDA Agricultural Marketing Service Cotton Classing Office in Memphis, TN.

Given that yield response was expected to be parabolic with respect to PPD (Holliday), the following quadratic yield response function was estimated using the lint yield and PPD data:

$$(6)\quad \begin{aligned} Y(PPD) = {} & \beta_1 + \beta_2 PPD_{i,j} + \beta_3 PPD_{i,j}^2 + \beta_4 dD97 \\ & + \beta_5 D97 \times PPD_{i,j} + \beta_6 D97 \times PPD_{i,j}^2 + w_{i,j} + v_{i,j} + e_{i,j}, \end{aligned}$$

where PPD is plant population density (plants m^{-2}) for treatment i in the j^{th} experimental block; D97 is a binary 0-1 variable for cotton produced in the 1997 growing season; β_k are parameters estimated using maximum likelihood; w is the random error associated with the j^{th} experimental unit that received treatment i; v is the random error associated with each year of the experiment; and e is the residual random error term. The mixed model procedure in SAS (Littell et al.) was used to estimate the yield response function specified in equation (6).

The binary intercept and slope variables were specified to account for the potential of a different yield response in 1997. The 1997 growing season was an El Nino year with very cool growing conditions relative to 1998 through 2000 and historical weather averages for the area. . Total growing degree days (base 15.6°C) in 1997 was 1,036 (1 Apr through 31 Oct) compared with an average of 1,275 for 1998 through 2000 and a longer term average of 1,271 for 1975 through 2000 (U.S. Department of Commerce). Only one other year between 1975 and 2000 had growing degree days as low as what was observed in 1997. The soil type for the plots in 1997 was also different from the soil type for the plots in 1998 through 2000. The following yield level hypothesis was tested using the binary intercept and slope variables: H_O:$\beta_4=\beta_5=\beta_6=0$—yields were not different in 1997; H_A: $\beta_4=\beta_5=\beta_6\neq0$—yields were different in 1997. The following yield hypothesis was tested using the binary intercept and slope variables: H_O: $\beta_5=\beta_6=0$—yield response was not different in 1997; H_A: $\beta_5=\beta_6\neq0$—yield response was different in 1997. If yield response was different for 1997 versus 1998 through 2000, then the 1998 through 2000 model was used to evaluate net revenue response to PPD; otherwise the 1997 through 2000 model was used to evaluate net revenue response to PPD.

Prices. Quotations collected by the U.S. Department of Agriculture, Agricultural Marketing Service were used to estimate premiums and discounts from base quality prices for each PPD treatment. Relevant quotations for Tennessee are from the North Delta market, which includes northeast Arkansas, Missouri, and west Tennessee. The area market reporter determines daily prices by interviewing market participants and collecting sales information. The accuracy of spot price quotations for the North Delta is unknown because there has not been an objective evaluation of the price differences reported by the Agricultural Marketing Service for this region (Ethridge and Hudson). The statistical reliability of spot price quotations is difficult to determine because information about sample characteristics such as number of observations and representativeness are not known (Brown et al.). Irrespective of these data limitations, we assume North Delta spot quotes reflect price differences for farmers in Tennessee.

Season average spot base prices and price differences for the 1993/94 through 2001/02 marketing years were used in the analysis of the UNRC PPD decision. Starting in 1993, grade was divided into color and leaf for pricing by the industry. Prior to that time, grade was reported as a composite of color and trash for pricing by the industry. Consequently, prices reported after August 1993 were used to determine lint prices in the analysis. Between 1993 and 2001, season average base quality lint prices varied from \$0.71 kg^{-1} and \$1.92 kg^{-1} with a median base price of 1.51 kg^{-1}. The equation used to calculate prices differences for fiber quality as influenced by UNRC PPD using North Delta market spot price data is:

(7) $$PD^{YR}_{i,j} = P^{cls}_{i,j} + P^{m}_{i,j} + P^{s}_{i,j} + P^{u}_{i,j} + P^{e}_{i,j},$$

where PD is the total price difference for each treatment i in the j^{th} experimental block from the base price of cotton (\$ kg^{-1}) for fiber quality obtained in year t of the experiment, YR is price year between 1993 and 2001. P^{cls} is the price difference for the combination of color grade, leaf grade, and staple (\$ kg^{-1}); P^{m} is the price difference for micronaire (\$ kg^{-1}); P^{str} is the price difference for strength (\$ kg^{-1}); P^{u} is the price difference for length uniformity (\$ kg^{-1}); and P^{e} is the price difference for extraneous matter (\$ kg^{-1}).

Price differences as a function of plant population [PD(POP)] for equation (1) were estimated using the price differences calculated using equation (7) and the mixed model procedure (Littell et al):

$$\text{(8)} \quad \begin{aligned} PD(PPD) = {} & \alpha_1 + \alpha_2 PPD_{i,\,j} + \alpha_3 D97 + \alpha_4 \times D97 \times PPD_{i,\,j} \\ & + \alpha_5 BP + \alpha_6 BP \times PPD_{i,\,j} + x_{i,\,j} + z_{i,\,j} + f_{i,\,j}, \end{aligned}$$

where α_j are parameters to be estimated using maximum likelihood; BP is base quality spot prices for the 1993 through 2001 marketing years, x is the random error associated with the j^{th} experimental unit that received treatment i; z is the random error associated with each year of the experiment; and f is the residual random error term.

Transgenic Variety Costs. Costs for the two transgenic varieties used in the UNRC experiment were used to calculate net returns for the alternative PPD decision and technology fee scenarios described previously. The assumed costs for PM 1220 RR, a glyphosate-tolerant (Roundup Ready) variety, are \$1.94 kg^{-1} for the seed and \$22.64 ha^{-1} for the technology fee (Monsanto Corporation). PM 1220 RR is classified as having an SVC value of 9,261 seeds kg^{-1} (Monsanto Corporation). The assumed costs for PM 1218 BR, a stacked gene glyphosate-tolerant, Bt variety are \$2.51 kg^{-1} for the seed and \$79 ha^{-1} for the technology fee (Monsanto Corporation). PM 1218 BR is classified as having an SVC value of 10,634 seeds kg^{-1} (Monsanto Corporation). PPS^{Farmer} was assumed to be the average ratio of plants established to seeds planted prior to thinning of 0.64 measured over the four years of the experiment.

Results and Discussion

Lint Yields. The lint yield response function for UNRC plant population density estimated from the experimental data is presented in Table 1. The coefficients for quadratic yield response to PPD for 1998 through 2000, PPD and PPD^2, have the hypothesized signs and are significantly different from zero ($p = 0.01$). Production function results also indicate that lint yield response to PPD for 1997 was different from the yield response for 1998 through 2000. The estimated coefficient for the binary variable D97 for yields in 1997 is significant ($p = 0.05$) and has a negative sign. In addition, the binary slope coefficients, D97×PPD and D97×PPD^2, were also statistically significant at the 10% and 5% probability levels, respectively. Taking all three binary coefficients together, the likelihood ratio test indicates that 1997 lint yields were smaller than the yields for UNRC for 1998 through 2000. Taking both slope coefficients together, the likelihood ratio test indicates that yield response to PPD was different for 1997.

As indicated in Figure 1, yield response to PPD in 1997 was much more concave for 1997 than for 1998 through 2000. The maximum lint yield of 715 kg ha^{-1} in 1997 was achieved at a PPD of 25.36 plants m^{-2} (253,648 plants ha^{-1}). The 1997 yield maximum was 254 kg ha^{-1} (55%) more than the 461 kg ha^{-1} yield achieved at the average minimum PPD in the experiment of 6.7 plants m^{-2} (66,618 plants ha^{-1}). Unfortunately, it cannot be directly determined if the difference in yield response to plant population in 1997 was due to weather, soil type, or a combination of weather and soil.

Lint yield response to PPD for 1998 through 2000 was not nearly as concave as the response function for 1997 (Figure 1). A maximum yield of 1,044 kg ha^{-1} for UNRC for 1998 through 2000 was achieved at a PPD of 26.6 plants m^{-2} (266,206 plants ha^{-1}). The yield maximum for 1998 through 2000 was only 68 kg ha^{-1} (7%) more than the 976 kg ha^{-1} yield achieved at the average minimum PPD in the experiment of 6.7 plants m^{-2}.

Lint Prices. The lint price difference response function for UNRC PPD estimated from the experimental data is presented in Table 1. The coefficient for PPD is significant ($p=0.05$) and has a negative sign, indicating that higher PPDs caused lower fiber quality and larger price discounts for UNRC. Lint price discounts vary from −\$0.08 kg^{-1} for the average minimum PPD in the experiment of 6.7 plants m^{-2} to −\$0.15 kg^{-1} for the average maximum PPD in the experiment of 38.2 plants m^{-2}. Price discounts for fiber quality for the 1997 data were significantly different from those observed with the 1998 through 2000 data. All of the plots uniformly received extraneous matter discounts in 1997. The coefficient for base price, BP, is also significant (p=0.05) and indicates that the relative size of the discounts for fiber quality rise with higher base prices.

Net Revenues. Net revenues (NRs) for alternative UNRC PPD decision criteria and technology fee scenarios for the glyphosate-tolerant (Roundup Ready) variety are presented in Table 2. Revenues and costs for the stacked gene glyphosate-tolerant, Bt (stacked gene) variety are presented in Table 3. The median base price of \$1.51 kg^{-1} for the 1993 through 2001 marketing years and the lint yield and price difference response functions for 1998 through 2000 were used to calculate NRs.

For the Roundup Ready variety, planting UNRC using the Extension Service recommended PPD of 24.71 plants m^{-2} results in a seed cost of \$86 ha^{-1} and a technology fee of \$33 ha^{-1} under the current UNRC exception policy (Current Exception). By contrast, seed costs and technology fees for the stacked gene variety are \$111 ha^{-1} and 114 ha^{-1}, respectively. Allowing an unlimited UNRC exception to the per bag technology fee (Unlimited Exception) respectively saves farmers \$11 ha^{-1} and \$35 ha^{-1} over the current UNRC exception policy for the Roundup Ready and stacked gene varieties. Consequently, the unlimited UNRC exception policy produces the largest NR among the four technology fee policies evaluated for the Extension Service PPD decision criterion. Modifying the current wide-row policy to have a larger SDR of 308,875 plants ha^{-1} (UNRC SDR) rather than the current SDR of 154,437 plants ha^{-1} over which to spread the technology fee produced the second largest NR. Under the UNRC

SDR policy, the technology fee is \$0.67 kg^{-1} versus \$1.33 kg^{-1} under the current wide-row SDR policy. The third largest NR is produced with current UNRC exception policy. For a farmer that is subject to the current wide-row policy rather than the current UNRC exception policy, the technology fees are about twice as large as the fees under the current UNRC exception and produced the lowest NR.

NR results indicate that farmers may be able to improve the profitability of UNRC by substantially reducing their target PPD from the 24.71 plants m^{-2} Extension Service decision rule. Because of the relatively small yield response to increasing PPD, the profit maximizing PPD is 43% smaller than the Extension service PPD decision rule (14.15 plants ha^{-1} versus 24.71 plants m^{-2}) under the current UNRC exception when using the Roundup Ready variety. There is a small tradeoff in reduced yields with the lower PPD compared with the 34% savings (\$41 ha^{-1}) in seed costs and technology fees by using the lower seeding rate of 25 kg ha^{-1}. A reduction in the price discount for fiber quality (\$0.02 kg^{-1}) also occurs from using the lower PPD level. Profit maximizing net revenues under the current UNRC exception are 2% (\$29 ha^{-1}) higher than for the Extension Service PPD decision criterion. The costs savings and net revenue gains by using the profit maximizing PPD decision rule are larger for the stacked gene variety (Table 3).

Using profit maximization as the PPD decision criterion, NRs are the largest under the wide-row policy that uses a seed drop rate of 308,875 plants ha^{-1} (UNRC SDR) to determine the technology fee per bag of seed. The second largest profit maximizing NR occurs under the UNRC exception policy with no limit on bags excepted (Unlimited) followed by the current UNRC exception and the current wide-row policies. Under profit maximization, the largest technology fees are generated under the current UNRC exception while the largest revenues for the seed company are generated under the UNRC exception with no limit on bags excepted.

For the Roundup Ready variety, optimal PPDs under profit maximization for the alternative technology fee scenarios ranged from a low of 10.34 plants m^{-2} under the current wide-row policy to 15.04 plants m^{-2} under the UNRC exception policy with no limit on bags exempted. As indicated previously, agronomists are concerned that too low a PPD in UNRC may reduce stripper harvest efficiency and cause weed problems. The potential consequences of these production problems are not reflected in the NRs calculated using the yield and price functions estimated from the experimental data. However, NRs for the "agronomic minimum" PPD of 15.5 plants m^{-2} are almost identical to the profit maximizing NRs for all technology fee scenarios except the current wide-row policy at the median base lint price of \$1.51 kg^{-1}. At a median base price of \$1.51 kg^{-1}, results indicate that farmers may be able to maximize profits for UNRC by planting for a target PPD of about 15.5 plants m^{-2}.

Figure 2 illustrates the relationship between lint price and the profit maximizing PPD for the Roundup Ready variety. The upper horizontal line represents the Agricultural Extension Service recommended PPD while the lower horizontal line represents the average minimum PPD observed in the study of 6.7 plants m^{-2}. The middle horizontal line represents the "agronomic minimum" PPD of 15.5 plants m^{-2}. The curved lines represent profit maximizing PPDs for the alternative technology fee scenarios for lint prices between \$0.70 kg^{-1} and \$1.90 kg^{-1}. The point where the curved lines intersect the "agronomic minimum" PPD level indicates where lint prices above that point have an impact on profit maximizing PPD.For example, under the current UNRC exception, base quality lint prices below \$1.60 kg^{-1} suggest that the "agronomic minimum" PPD decision rule may be used while the profit maximizing PPD decision rule may be used for base lint prices above \$1.60 kg^{-1}. With the stacked gene variety, the net revenue results suggest that "agronomic minimum" PPD rule should be used regardless of lint price.

Conclusions

Farmers are concerned about the high costs of transgenic seed and technology fees associated with the large plant population densities recommended for ultra-narrow row cotton production. This study evaluated the effects of alternative plant population density decision criteria on net revenues for ultra-narrow-row for alternative lint price and transgenic seed cost scenarios. Results indicate that farmers may be able to maximize profits for ultra-narrow-row cotton by seeding for a target plant population density of approximately 15.5 plants m^{-2}. In an evaluation of alternative transgenic variety pricing policies, the largest technology fees are generated under the current ultra-narrow-row UNRC exception policy while the largest seed revenues for the seed company are generated under the under the UNRC exception policy with no limit on bags exempted. The most favorable technology fee policy for farmers was a modification of the current wide-row policy that uses a higher seeding rate for the calculation of the technology fee.

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Table 1. Lint Yield and Price Difference Response Functions for the UNRC Plant Population Density Decision Analysis

Variables/Items[†]	Lint Yield (kg ha^{-1})	Price Difference (\$ kg^{-1})
Intercept	923.4***	−0.01243
	(22.5)	(−0.72)
PPD	9.051***	−0.00175**
	(3.38)	(−3.15)
PPD^2	−0.1704***	NA
	(−2.89)	
D97	−674.9***	−0.11450***
	(−2.34)	(−5.93)
D97×PPD	27.7281**	0.00247***
	(1.92)	(4.82)
D97×PPD^2	−0.5551*	NA
	(−1.53)	
BP	NA	−0.02685**
		(−3.21)
BP×PPD	NA	−0.00016
		(−0.43)
$\beta_4=\beta_5=\beta_6=0$	14.7***[,‡]	NA
$\beta_4=\beta_6=0$	21.6***[,¶]	NA
$\alpha_4=\alpha_5=0$	----	17.4***[,§§]
Observations	86	775

[†]PPD is plant population density (plants m^{-2}), D97 is a 0-1 binary variable where D97=1 if year=1997; else D97=0 otherwise, and BP is base quality price for the 1993/94 through 2001/02 marketing years.

*,**,*** Significantly different from zero at the 0.1, 0.05, and 0.01 levels of significance, respectively.

[‡]Chi-square statistic for the likelihood ratio test that lint yields for 1997 were significantly different from lint yields for 1998-2000.

[§]Chi-square statistic for the likelihood ratio test that lint yield response to PPD for 1997 were significantly different from lint yields for 1998-2000.

[¶]Chi-square statistic for the likelihood ratio test that lint price difference response to PPD for 1997 were significantly different from price response for 1998-2000.

Table 2. Yields, Price Differences, Seeding Rates, Seed Costs, and Net Revenues for Alternative UNRC Plant Population Decision Density (PPD) Criteria for a Glyphosate-Tolerant (Roundup) Variety[†‡]

			Profit Maximum/Technology Fee Policy Scenario[§]			
	Extension	Agronomic	Wide-Row		UNRC Exception	
Item	Recommendation	Minimum	Current SDR	UNRC SDR	Current	Unlimited
PPD m^{-2}	24.71	15.50	10.34	12.68	14.15	15.04
Lint Yield (kg ha^{-1})	1,043	1,023	999	1,011	1,017	1,021
Lint Price Difference ($ kg^{-1})	-0.10	-0.09	-0.07	-0.08	-0.08	-0.08
Net Lint Price ($ kg^{-1})	1.41	1.42	1.44	1.43	1.43	1.43
Seeding Rate (kg ha^{-1})	44	28	18	23	25	27
Seed Cost ($ ha^{-1})	86	54	36	44	49	52
Tech Fee Wide-Row						
Current SDR ($ ha^{-1})	59	37	25	NA	NA	NA
UNRC SDR ($ ha^{-1})	29	18	NA	15	NA	NA
Tech Fee UNRC Exception						
Current ($ ha^{-1})	33	29	NA	NA	29	NA
Unlimited ($ ha^{-1})	22	22	NA	NA	NA	22
Net Revenue Wide-Row						
Current SDR ($ ha^{-1})	1,321	1,366	1,373	NA	NA	NA
UNRC SDR ($ ha^{-1})	1,351	1,385	NA	1,387	NA	NA
Net Revenue UNRC Exception						
Current ($ ha^{-1})	1,347	1,374	NA	NA	1,375	NA
Unlimited ($ ha^{-1})	1,358	1,381	NA	NA	NA	1,381

[†]Cotton variety PM 1220 RR with a $1.94 kg^{-1} cost for the seed and a $22.64 ha^{-1} technology fee.
[‡]Calculated using a base lint quality price of $1.51 kg^{-1}.
[§]See text for the description of the alternative technology fee policy scenarios.

Table 3. Yields, Price Differences, Seeding Rates, Seed Costs, and Net Revenues for Alternative UNRC Plant Population Decision Density (PPD) Criteria for a Stacked Gene Glyphosate –Tolerant (Roundup), Bt Variety†‡

			Profit Maximum/Technology Fee Policy Scenario§			
	Extension	Agronomic	Wide-Row		UNRC Exception	
Item	Recommendation	Minimum	Current SDR	UNRC SDR	Current	Unlimited
PPD m^{-2}	24.71	15.50	6.66	6.66	10.20	13.01
Lint Yield (kg ha^{-1})	1,043	1,023	976	976	998	1,012
Lint Price Difference ($ kg^{-1})	-0.10	-0.09	-0.07	-0.07	-0.07	-0.08
Net Lint Price ($ kg^{-1})	1.41	1.42	1.44	1.44	1.44	1.43
Seeding Rate (kg ha^{-1})	44	28	12	12	18	23
Seed Cost ($ ha^{-1})	111	70	30	30	46	58
Tech Fee Wide-Row						
Current SDR ($ ha^{-1})	209	131	56	NA	NA	NA
UNRC SDR ($ ha^{-1})	105	66	NA	28	NA	NA
Tech Fee UNRC Exception						
Current ($ ha^{-1})	114	101	NA	NA	94	NA
Unlimited ($ ha^{-1})	79	79	NA	NA	NA	79
Net Revenue Wide-Row						
Current SDR ($ ha^{-1})	1,146	1,256	1,322	NA	NA	NA
UNRC SDR ($ ha^{-1})	1,250	1,322	NA	1,350	NA	NA
Net Revenue UNRC Exception						
Current ($ ha^{-1})	1,241	1,286	NA	NA	1,293	NA
Unlimited ($ ha^{-1})	1,276	1,308	NA	NA	NA	1,310

†Cotton variety PM 1218 BR with a $1.94 kg^{-1} cost for the seed and a $22.64 ha^{-1} technology fee.
‡Calculated using a base lint quality price of $1.51 kg^{-1}.
§See text for the description of the alternative technology fee policy scenarios.

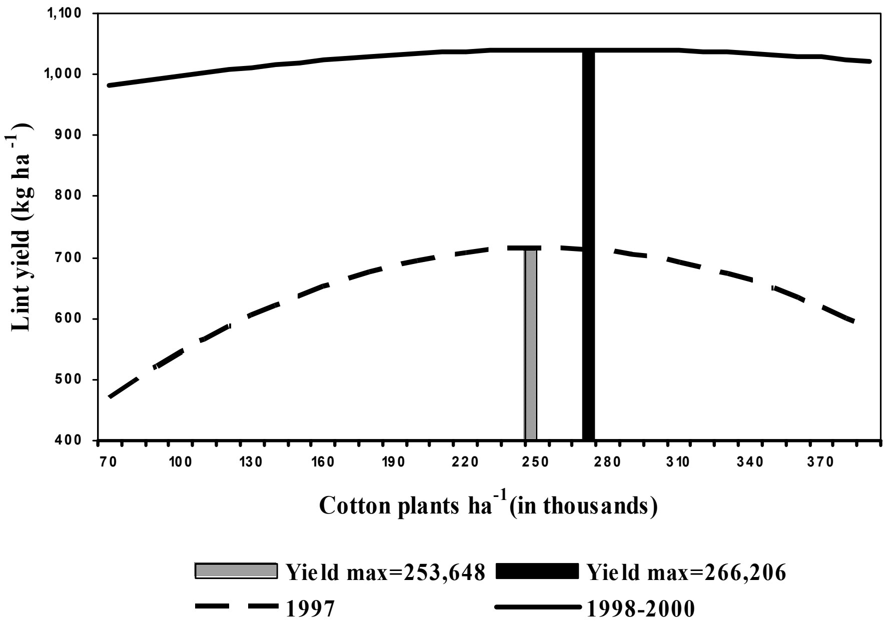

Figure 1. Mean Lint Yield Response to Plant Population Density for UNRC Production, 1997-2000 at Milan, TN

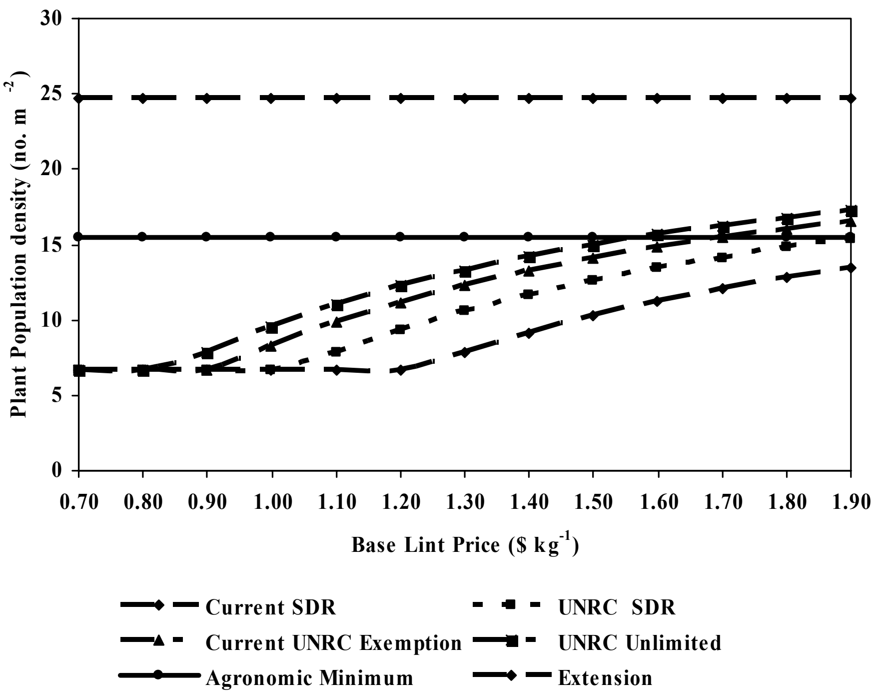

Figure 2. Optimal Plant Population Densities for a Glyphosate-Tolerant (Roundup) Variety for Alternative Base Quality Lint Prices†

†See text for the description of the alternative technology fee policy scenarios.