SMALL GRAINS

Yield, Quality, and Profitability of Cotton Produced at Varying Plant Densities

Craig W. Bednarz,* W. Don Shurley, W. Stanley Anthony, and Robert L. Nichols

ABSTRACT

Modifying fruit distribution through varying plant density may impact cotton (*Gossypium hirsutum* L.) fiber quality. This study was conducted to determine how lint yield, fiber quality, and profitability of cotton may be manipulated through plant density. Two cotton cultivars were overseeded and hand-thinned to 3.6, 9.0, 12.6, and 21.5 plants m^{-2} at two University of Georgia experiment stations in 2001 and 2002. After the studies were machine-harvested each year, the seed cotton was shipped to the USDA-ARS Cotton Ginning Research Unit in Stoneville, MS, for ginning. While ginning, six lint samples were collected per plot and delivered to Cotton Incorporated (Cary, NC) for fiber quality analyses. Net returns were then calculated from yield, quality, and seed cost data. Lint yields were greatest at 12.6 plants m^{-2} and lowest at 3.6 plants m^{-2}. Of the fiber properties investigated, micronaire and fineness were most affected by plant density. In addition, quality adjustments in price were greatest for micronaire. Thus, avoidance of price discounts for high-micronaire fiber may occur through adjustments in seeding rate and plant density. Net returns above seed costs were greatest at 12.6 plants m^{-2} for both cultivars. One cultivar consistently outperformed the other in fiber quality. Results from this study support the findings of others that fiber properties are highly genetically influenced. Thus, to maximize fiber quality, cultivar selection is of greatest importance while management of plant density to maintain or maximize genetic potential is secondary.

RECENT ADVANCES in yarn-spinning and fabric-manufacturing technologies have improved the fiber-processing efficiency of the U.S. textile industry (Deussen, 1992). To operate at peak efficiency, however, these newer technologies must process cotton fibers of high quality (Faerber, 1995). To reflect this demand, the USDA Commodity Credit Corporation (CCC) modified the Schedule of Premiums and Discounts for Upland and Extra Long Staple Cotton. The most notable modifications to the schedule were the inclusion of fiber length uniformity (a measure of the degree of length uniformity of the fibers in a sample) and an increase in the fiber strength base (level of fiber strength at which no price premium or discount is received). Beginning with the 2000 crop, price premiums or discounts were applied to cotton fibers that exceed or fail to meet these newly established standards for fiber length uniformity and fiber strength. Some textile manufacturers, however, have already adopted their own standards for fiber length uniformity and have even begun to discriminate against cottons produced in certain regions of the U.S. Cotton Belt simply because historical records from these regions indicate they generally do not meet the in-house standards. Thus, if cotton produced in the USA is to remain competitive on a global market, fiber quality must meet these new standards.

Unfortunately, between 1998 and 2002, the quality of U.S. cotton actually declined. Some have speculated this deterioration is due to the widespread adoption of transgenic cotton cultivars that were inadequately tested for yield and fiber quality before their release. Others have conjectured the decline in fiber quality resulted from changes in crop management that arose from adoption of transgenic cotton cultivars. For instance, technology fees associated with transgenic cotton cultivars are an economic incentive for the grower to reduce seeding rates. Bednarz et al. (2000) illustrated the fruiting habit of cotton may impart yield stability with reduced seeding rates/plant densities through the production of fruit on longer sympodial branches, additional main-stem nodes, and additional monopodial branches. It is generally believed, however, that lint produced on monopodial branches, more apical main-stem nodes, and more distal sympodial branch fruiting positions is lower quality (Bernhardt and Phillips, 1986; Knight et al., 1988; Crawley et al., 1996). As plant density is decreased, the percentage of the total yield produced at these exterior fruiting sites is increased (Bednarz et al., 2000). Thus, it seems reasonable that less desirable fiber quality may result from reduced plant densities.

Since the early 1970s, a plethora of cotton plant density studies have been published, with the primary focus being lint yield. While an abundance of information regarding the relationship between plant density and lint yield exists, additional information is needed concerning the effects of plant density on fiber quality. Unlike the current study, the ginning technique employed in most of the previous work did not mimic the commercial ginning process, which may have resulted in unreliable fiber quality data. In addition, newer technology to determine cotton fiber quality (i.e., the Advanced Fiber Information System, Uster Technologies, Charlotte, NC) was unavailable in the 1970s. Finally, seed costs have increased greatly since the early 1970s. In the 1970s, many growers planted their own seed from the previous crop. Inflation, price premiums, and technology fees of transgenic cultivars have resulted in in-

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C.W. Bednarz, Univ. of Georgia, Coastal Plain Exp. Stn., P.O. Box 748, Tifton, GA 31793; W.D. Shurley, Univ. of Georgia, Rural Dev. Cent., P.O. Box 1209, Tifton, GA 31793; W.S. Anthony, USDA-ARS Cotton Ginning Res. Unit, P.O. Box 256, Stoneville, MS 38776; and R.L. Nichols, Cotton Incorporated, 6399 Weston Parkway, Cary, NC 27513. Received 24 Feb. 2004. *Corresponding author (cbednarz@tifton.uga.edu).

Published in Agron. J. 97:235–240 (2005).
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677 S. Segoe Rd., Madison, WI 53711 USA

Abbreviations: AFIS, advanced fiber information system; HVI, high-volume instrument.

creased seed costs. Increased seeding rates in the 1970s may have resulted in only a small increase in variable costs, whereas today, increased seeding rates would result in a much greater increase in variable costs. Thus, the objectives of this investigation were to determine how lint yield, fiber quality, and profitability of cotton are affected by plant density.

MATERIALS AND METHODS

Plot Establishment and Maintenance

Experiments were conducted in 2001 at the Coastal Plain Experiment Station in Tifton, GA, on a Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) and in 2001 and 2002 at the Southwest Branch Experiment Station in Plains, GA, on a Greenville sandy clay loam (fine, kaolinitic, thermic Rhodic Kandiudults). In March of each year, 672 kg ha^{-1} of 3–9–18 plus micronutrients (8% Ca, 2% Mg, 9% S, 0.13% B, 0.10% Fe, 1% Mn, and 0.35% Zn) was broadcast and harrow-incorporated. Trifluralin (α,α,α-trifluoro-2,6-dinitro-*N,N*-dipropyl-*p*-toluidine; 1.12 kg a.i. ha^{-1}) was then broadcast and harrow-incorporated immediately before ripping and bedding. While ripping and bedding, 32 kg a.i. ha^{-1} of 1,3-dichloropropene was injected under the row for nematode control at Tifton. All other fertility, weed, and insect pest control practices were in accordance with the University of Georgia Cooperative Extension Service Guidelines (Brown et al., 2001). Water stress was minimized with overhead sprinkler irrigation in all studies. Cotton ('DPL 458 BR' and 'FM 966') was overseeded on 10 and 14 May 2001 at Tifton and Plains, respectively, and 12 May 2002 at Plains and hand-thinned to 3.6, 9.0, 12.6, and 21.5 plants m^{-2} on stand establishment (i.e., approximately 3 wk after planting). The two cultivars chosen for this study were selected on the basis of fiber quality. One cultivar, DPL 458 BR, generally does not produce highly desirable fiber qualities while the other cultivar, FM 966, does. Since the focus of this study was fiber quality, both cultivars were managed as nontransgenic. Each plot was four rows (0.9-m centers) wide and 38 m long. Harvest aids were applied at approximately 70% open boll in each study and were a combination of tribufos (*S,S,S*-tributyl phosphorotrithioate; 0.321 kg a.i. ha^{-1}) plus thidiazuron (*N*-phenyl-*N*′-1,2,3-thiadiazol-5-ylurea; 0.093 kg a.i. ha^{-1}) plus ethephon [(2-chloroethyl)phosphonic acid; 1.103 kg a.i. ha^{-1}].

Data Collection

Immediately before machine harvest, approximately 1 m of row was removed from each end of all plots with a tractor-mounted, 2.1-m-wide Bush Hog mower (Bush Hog, Incorporated, Selma, AL) to avoid inaccurate measures of plot yield and fiber quality due to the end-of-row effect (Holman and Bednarz, 2001). After all plots were machine-harvested, the seed cotton was shipped to the USDA-ARS Cotton Ginning Research Unit in Stoneville, MS, for ginning. This facility is unique in its capacity to simulate commercial ginning on experimental samples. The ginning sequence at the Stoneville lab was cylinder cleaner, drier (52°C), stick machine, cylinder cleaner, extractor feeder, gin stand, and two stages of saw-type lint cleaning. The gin (Anthony and McCaskill, 1974) and ginning sequence are consistent with commercial ginning operations for spindle-harvested cotton.

While ginning, a total of six fiber samples were collected per plot. All six samples were delivered to Cotton Incorporated (Cary, NC) for fiber quality analyses. Fiber quality from three samples from each plot was determined using an Uster Technologies (Charlotte, NC) model 900-A high-volume instrument (HVI). An HVI uses a sample of unaligned fibers to measure fiber properties, including several that are used in the USDA Agricultural Marketing Service fiber grading. Fiber quality from the other three samples from each plot was determined using an Uster Technologies (Charlotte, NC) advanced fiber information system (AFIS) instrument. An AFIS measures the properties of approximately 3000 individual fibers by optical analysis. Therefore, in the current study, approximately 9000 fibers per plot were measured. While HVI is commonly used for grading and determining the preferred composition of bale lay-downs for fiber processing, AFIS is typically used in textile mills for process control to increase the efficiency of spinning and yarn quality. In the current study, the AFIS function that expresses the results on a weight basis (rather than by fiber number) is reported because textile mills manage their fiber stock by weight. Single AFIS measurements have information about the mean and variance of fiber properties that HVI does not possess. The AFIS measurements presented herein include (on a weight basis) length [L(w)] in mm, percentage variation in length [L(w)CV], upper quartile length [UQL(w)] in mm, percentage short fiber content [SFC(w)], fineness in mg km^{-1}, and the maturity ratio quotient. Short fibers are those less than or equal to 1.27 cm in length. Fineness is the mass of one thousand meters of fibers. The maturity ratio is the quotient of fibers with the circularity (an index of normalized fiber circumference) of 0.5 or greater divided by those with the circularity equal to or less than 0.25. It should be emphasized that none of the current cotton plant density literature contains AFIS data.

Economic Analysis

Net return above seed costs was calculated for each HVI fiber quality sample. Except for seed, all other inputs and costs were fixed regardless of plant density or cultivar. As previously indicated, although one cultivar used in this study was transgenic, both cultivars were managed as nontransgenic, and readers should be cautioned when interpreting the economic analysis between cultivars. The net return for each plant density and variety for each year and location was calculated as:

$$\mathrm{NR}_{ijk}^{xyz} = (Y_{ij}^{xyz} \times P_{k}^{x}) - S_{i}^{xz}$$

where NR = net return per hectare in year *x*, location *y*, and variety *z* for plant density *i*, yield rep *j*, and quality sample *k*; *Y* = yield (kg ha^{-1}) in year *x*, location *y*, and variety *z* for plant density *i* and yield rep *j*; *P* = loan rate (¢ kg^{-1}) for year *x* and quality of sample *k*; and *S* = seed cost ($ ha^{-1}) in year *x* for variety *z* and plant density *i*.

Cotton lint was valued at the loan rate adjusted for fiber quality. Base loan rates (no premiums or discounts for fiber quality) for 2001 and 2002 were \$1.1422 kg^{-1} and \$1.1440 kg^{-1}, respectively (USDA, 2001a, 2002).

Hand-classed leaf grade data were unavailable for this study. High-volume instrument percentage trash measurements were recorded, however, in all fiber samples from the study. High-volume instrument percentage trash has been shown to be related to the hand classer's leaf grade (USDA, 2001b). High-volume instrument percentage trash did not differ between cultivars or population densities (data not shown). In addition, the mean HVI percentage trash corresponded to a hand classer's leaf grade of 3. Thus, Leaf Grade 3 was used for all economic analyses.

Seed cost per bag, including technology fee if applicable, for each variety and year was obtained from company sales representatives. The price per bag was provided by the company as the typical price paid by Georgia farmers. The seed cost per hectare was calculated for each variety and plant density based on 0.9-m row spacing. Final plant density was assumed to be 85% of the actual seeding rate. For example, seed costs for 3.6 plants m^{-2} was based on 4.2 seeds m^{-2}.

The technology fee for DPL 458 BR was capped at a maximum of \$101.27 ha^{-1}. This is the exception rate established by Monsanto (St. Louis, MO). If the technology fee for the entire farm averages more than \$101.27 ha^{-1}, the fee may be reduced to this level. In this study, the technology fee for DPL 458 BR was reduced to \$101.27 ha^{-1} at plant densities 12.6 and 21.5 plants m^{-2}.

Statistical Analyses

The experimental design was a split plot in space where the three year–location combinations (Plains and Tifton 2001 and Plains 2002) were the main plots. The randomized complete block was comprised of replications and the factorial combinations of variety and levels of plant density. The data collected were analyzed using Proc MIXED (SAS Inst., 2000) using a mixed model with the factorial arrangement of treatments as fixed effects and all other effects considered as random. Year by each of three treatment effects was used as a source of error to test their respective treatment effects. The model statement option determined the correct degrees of freedom for each of the fixed effect tests based on the significance levels of the various random effect terms. Least square means were obtained from the analysis results.

RESULTS AND DISCUSSION

Lint Yield

Several studies have shown decreased lint percentage with increased plant density (Hawkins and Peacock, 1971; Bridge et al., 1973; Buxton et al., 1979; Smith et al., 1979; Gannaway et al., 1995). Our studies illustrated a similar pattern (Table 1). While the exact mechanism of this phenomenon is unknown, it likely results from increased interplant competition, resulting in decreased seed size (Hawkins and Peacock, 1971; Bridge et al., 1973; Buxton et al., 1979) and lint weight per seed with increased plant density.

Bridge et al. (1973) found the highest lint yields in Mississippi occurred at a plant density range of 7.0 to 12.1 plants m^{-2}. In Arkansas, the highest yields occurred in irrigated cotton at 13.6 plants m^{-2} (Smith et al., 1979). Hawkins and Peacock (1971) found the highest yields in Georgia occurred at 9.6 to 14.4 plants m^{-2}. In Texas, Fowler and Ray (1977) found plant densities ranging from 7.9 to 15.5 plants m^{-2} produced the highest lint yields. In the current study, lint yields were greatest at 12.6 plants m^{-2} and lowest at 3.6 plants m^{-2} (Table 1). Thus, the yield response to plant density in our studies was similar to previous reports.

Fiber Quality

With the exception of micronaire, most studies have found plant density had little effect on fiber quality (Hawkins and Peacock, 1971; Bridge et al., 1973; Baker, 1976; Fowler and Ray, 1977; Buxton et al., 1979). In the current study, HVI color, staple length, and length uniformity were unaffected by plant density yet greatly influenced by cultivar (Table 1). Fiber micronaire and fineness, however, were influenced by plant density (Tables 1 and 2), which is in agreement with others who observed reduced micronaire with higher plant densities (Hawkins and Peacock, 1971; Bridge et al., 1973; Baker, 1976; Fowler and Ray, 1977; Buxton et al., 1979). While the mechanism behind the reductions in micronaire and fineness remains unknown, one probable explanation is related to the more compact fruiting habit observed with greater plant densities. With increasing plant density, a greater percentage of the total lint yield arises from first sympodial position fruit at Main-Stem Nodes 7 through 11 (Bednarz et al., 2000). Fruit produced at these interior positions are generally of better fiber quality than those produced at more exterior fruiting positions (Bernhardt and Phillips, 1986; Knight et al., 1988; Crawley et al., 1996). Another explanation behind the reductions in micronaire and fineness may be associated with altered within-boll yield components. It is well documented that boll size is inversely related to plant density (Hawkins and Peacock, 1971, 1973; Bridge et al., 1973; Baker, 1976; Fowler and Ray, 1977; Buxton et al., 1979; Smith et al., 1979; Jones and Wells, 1997; Bednarz et al., 2000).

Table 1. Lint percentage, lint yield, and high volume instrument (HVI) fiber micronaire, strength, color, staple length, and length uniformity in plant density studies conducted at the University of Georgia Coastal Plain Experiment Station in 2001 and 2002.

Effect	Lint percentage	Lint yield	Micronaire	Strength	Color Rd	Color +b	Color grade	Staple length	Uniformity
	%	kg ha^{-1}		kN kg^{-1}				mm	%
Plant density (plants m^{-2})									
3.6	37.9	1246	4.3	280	77.2	8.5	31	27.6	81.6
9.0	37.6	1345	4.3	287	77.7	8.4	31	27.6	81.6
12.6	37.4	1376	4.2	291	77.7	8.3	31	27.8	81.8
21.5	37.4	1363	4.1	293	78.0	8.3	31	27.7	81.6
LSD (0.05)	0.4	102	0.1	11	0.7	0.1	—	0.3	0.4
Cultivar									
DPL 458 BR	36.9	1322	4.3	270	78.0	8.5	31	27.1	80.9
FM 966	38.2	1344	4.2	305	77.3	8.3	31	28.2	82.3
LSD (0.05)	0.3	85	0.1	8	0.5	0.1	—	0.2	0.3
Source of variation									
Plant density (PD)	*	*	**	*	NS†	NS	—	NS	NS
Cultivar (CV)	**	NS	**	**	**	**	—	**	**
PD × CV	NS	NS	NS	NS	NS	NS	—	NS	NS

* Significance at the 0.05 level.

** Significance at the 0.01 level.

† NS, nonsignificant.

Table 2. Advanced fiber information system (AFIS) fiber length by weight [L(w)], length by weight coefficient of variation [L(w) CV], upper quartile length by weight [UQL(w)], short fiber content by weight [SFC(w)], fineness (Fine), and maturity ratio in plant density studies conducted at the University of Georgia Coastal Plain Experiment Station in 2001 and 2002.

Effect	L(w)	L(w) CV	UQL(w)	SFC(w)	Fine	Maturity ratio
	mm	%	mm	%	mg km^{-1}	
Plant density (plants m^{-2})						
3.6	24.3	33.52	29.3	8.56	176	0.89
9.0	24.4	33.59	29.4	8.66	174	0.88
12.6	24.4	33.79	29.5	8.79	173	0.88
21.5	24.3	34.15	29.5	9.00	172	0.87
LSD (0.05)	0.3	0.50	0.3	0.39	3	0.01
Cultivar						
DPL 458 BR	23.9	33.33	28.9	8.87	181	0.87
FM 966	24.8	34.19	30.0	8.64	167	0.88
LSD (0.05)	0.4	1.06	0.2	0.68	5	0.01
Source of variation						
Plant density (PD)	NS†	*	NS	*	**	**
Cultivar (CV)	**	*	**	NS	**	**
PD × CV	NS	NS	NS	NS	NS	NS

* Significance at the 0.05 level.
** Significance at the 0.01 level.
† NS, nonsignificant.

Bednarz et al. (2003) documented that smaller bolls tend to contain smaller seeds with less weight of fibers per seed. Thus, altered within-boll yield components through increased plant density may also affect micronaire.

Under the current marketing system, high-micronaire cotton (micronaire value of 5.0 or greater) is discounted because it produces lower-strength yarns. To avoid high-micronaire cotton and the discounts associated with it, some growers opt to terminate their crops early. Early termination will result in lower micronaire but may also result in reduced fiber maturity (Bednarz et al., 2002). Due to their unacceptable dyeing characteristics, immature fibers are also undesirable. In the current study, increased plant density reduced micronaire but also reduced fiber maturity (Table 2). One mechanism for this decrease in fiber maturity may be related to the more compact fruiting habit of increased plant densities. If a greater percentage of the total yield arose at fewer fruiting positions through increased plant densities (as described above), then interboll competition for resources during boll filling may be increased, plausibly reducing fiber maturity. Even the highest plant density, however, produced fibers that are considered mature (i.e., maturity ratio above 0.80). Thus, increased plant density or cultivar selection for lower micronaire may be better methods of controlling high micronaire than early crop termination.

In the current study, fiber strength and plant density increased concurrently (Table 1), which has not been previously reported. This new observation may be related to the ginning technique employed. Seed cotton in the current study was ginned in a manner that is consistent with commercial ginning (i.e., with drying, precleaning, and lint cleaning). Seed cotton in all of the published literature on this subject was ginned with a small tabletop laboratory gin (i.e., with no drying, precleaning, and lint cleaning). Tabletop laboratory gins do not have a section that removes motes (unfertilized ovules) and their associated weak fibers. In addition, lint cleaning with ginning may remove some weaker fibers. Thus, ginning methodology employed in the current study may have illuminated fiber strength differences that remained hidden is previous studies.

Another possible mechanism leading to increased fiber strength may be related to fiber fineness. Presumably, the finer fibers produced in the high plant densities possessed a smaller lumen during the fiber-filling phase. This smaller lumen may have been more completely filled during the fiber-filling phase, leading to increased fiber strength.

High-volume instrument length uniformity and AFIS fiber length by weight coefficient of variation [L(w)CV] are both measures of the length uniformity of fibers in a sample. High-volume instrument length uniformity, the ratio between the mean fiber length and the mean fiber length of the longest one-half of the fibers in a sample, was unaffected by plant density (Table 1). Advanced fiber information system [L(w)CV], computed by measuring the individual fiber length of five subsamples of 3000 fibers each, increased with plant density (Table 2). Additionally, short fiber content [SFC(w)], or fibers ≤ 1.27 cm, increased with plant density (Table 2). While not significant, a trend was observed for increased upper quartile fiber length [UQL(w); the length of the longest 25% of the fibers in a sample] as plant density increased (Table 2). Thus, fiber length distribution was altered with increased plant density, the net effect being a decrease in length uniformity [L(w)CV] with no change in mean fiber length [L(w), Table 2].

Profitability

Nominal price premiums increased with plant density for color, leaf grade, staple length (C/L/S), fiber strength, and length uniformity (Table 3). Price premium for micronaire, however, significantly increased from 0.132 ¢ kg^{-1} at 3.6 plants m^{-2} to 0.308 ¢ kg^{-1} at 21.5 plants m^{-2} (Table 3).

Plant density × cultivar interactions were observed for net returns. The data, therefore, were not combined. The quality adjusted lint price per kilogram was lowest for DPL 458 BR at 3.6 plants m^{-2} (Table 4). Due to superior fiber quality, the adjusted lint price per kilo-

Table 3. Price premiums or discounts received for fiber color, leaf grade, and length (C/L/S); strength; micronaire; and length uniformity in plant density studies conducted at the University of Georgia Coastal Plain Experiment Station in 2001 and 2002.

Effect	C/L/S	Strength	Micronaire	Uniformity
	¢ kg^{-1}			
Plant density (plants m^{-2})				
3.6	3.036	−0.198	0.132	0.088
9.0	4.334	0.154	0.176	0.088
12.6	4.840	0.396	0.220	0.176
21.5	4.796	0.440	0.308	0.110
LSD (0.05)	2.904	0.638	0.088	0.132
Cultivar				
DPL 458 BR	2.662	−0.660	0.154	−0.020
FM 966	5.852	1.056	0.264	0.264
LSD (0.05)	7.678	0.440	0.110	0.088
Source of variation				
Plant density (PD)	NS†	NS	**	NS
Cultivar (CV)	NS	**	*	**
PD × CV	NS	NS	NS	NS

* Significance at the 0.05 level.
** Significance at the 0.01 level.
† NS, nonsignificant.

gram for FM 966 was greater than for DPL 458 BR at all plant densities. Seed costs, including technology fees if applicable, ranged from \$10.92 ha^{-1} at 3.6 plants m^{-2} to \$62.53 ha^{-1} at 21.5 plants m^{-2} for FM 966 and from \$42.01 ha^{-1} at 3.6 plants m^{-2} to \$154.05 ha^{-1} at 21.5 plants m^{-2} for DPL 458 BR. Net returns above seed costs were lowest for DPL 458 BR at 3.6 plants m^{-2} (Table 4). Net returns above seed costs were highest at 12.6 plants m^{-2} for both cultivars. It should be emphasized that the technology fee was included as a part of the seed cost of the transgenic cultivar, which caused the net return of the conventional cultivar to be artificially higher than the net return of the transgenic cultivar. Thus, readers should be cautioned when interpreting the economic analysis between cultivars.

CONCLUSIONS

The hypothesis behind this investigation suggested modified fruit distribution through varying plant density may impact fiber quality. Of the fiber properties investigated, micronaire and fineness were most affected by plant density. In addition, quality adjustments in price were greatest for micronaire. Results from other studies have shown cotton fiber length and strength are primarily under genetic control while micronaire and fineness are more influenced by the environment (May, 1999). In the current study, small gains in length and strength were made through modifications in plant density, but the greatest improvements in fiber quality were made in micronaire and fineness. Thus, avoidance of price discounts for high-micronaire fiber may occur through increased seeding rate and plant density. Finally, in terms of fiber quality, FM 966 consistently outperformed DPL 458 BR at all plant densities. This observation further supports the findings that fiber properties are highly genetically influenced. Thus, to maximize fiber quality, cultivar selection is of greatest importance while management of plant density to maintain or maximize genetic potential is secondary.

Table 4. Lint price per kilogram and net return per hectare in plant density studies conducted at the University of Georgia Coastal Plain Experiment Station in 2001 and 2002.

Cultivar	Plant density	Lint price	Net return
	plants m^{-2}	\$ kg^{-1}	\$ ha^{-1}
DPL 458 BR	3.6	1.13	1307.74
	9.0	1.17	1452.73
	12.6	1.18	1478.69
	21.5	1.18	1471.64
FM 966	3.6	1.22	1568.15
	9.0	1.21	1608.83
	12.6	1.22	1644.24
	21.5	1.22	1570.40
LSD (0.05)		0.02	179.35

ACKNOWLEDGMENTS

The authors thank Benjamin G. Mullinix, Jr. for assistance with the statistical analyses and T. Dudley Cook and Lola C. Sexton for the technical support. Appreciation is also extended to Dr. Mike D. Watson and Norma M. Keyes and the Cotton Incorporated Textile Services Laboratory staff for assistance with the fiber quality analyses and interpretation. The authors also thank the Georgia Agricultural Commodity Commission for Cotton and Cotton Incorporated for the financial support.

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