Planting date, plant density and irrigation management: Responses of recent Upland varieties in the San Joaquin Valley of California

R.B. Hutmacher [1], S.D. Wright [2], M.P. Keeley [1], B.H. Marsh [3], R. Delgado [1] and G. Banuelos [2]
[1] Univ. of California Shafter Res. & Ext. Ctr. & Univ. of CA Davis Agronomy & Range, Shafter CA USA
[2] Univ. of CA Cooperative Extension, Tulare CA, USA
[3] Univ. of CA Coop. Ext., Bakersfield, CA & Shafter Res. & Ext. Ctr., Shafter CA USA
Correspondence author rbhutmacher@ucdavis.edu

ABSTRACT

A three-year study was initiated in the San Joaquin Valley (SJV) to develop information on sensitivity of growth, lint yield and fiber quality responses to planting dates, planting density, and irrigation management practices in different varieties. Varieties included two non-Acala Upland and one Acala that represented a range of growth habits and maturity. The study was conducted at two locations for each year, one in a clay loam soil in the central SJV, the other in a sandy loam soil in the southern SJV. Among the variables evaluated, the largest yield responses within any variety were seen with changes in planting date; with the earlier (April) planting dates consistently out-yielding May plantings. Planting density effects on yields were greatest in April plantings, where higher plant populations tended to reduce yields, particularly in the Acala variety. Under lower yield conditions or with later planting dates, higher plant populations generally had little impact or even slightly improved yields. Delayed irrigations, which produced moderate levels of plant water stress compared with standard irrigation practices, often produced slightly higher yields in the non-Acala varieties, but either had no effect or slightly reduced yields in the longer-season Acala variety. Future efforts with data from this trial will focus on more detailed analysis of responses to irrigation and growth regulator treatments.

Introduction

Changes in California regulations on varieties allowed in the San Joaquin Valley Quality Cotton District combined with low commodity prices and increasing input costs have increased interest in alternatives to the Acala Upland and Pima varieties. Generally, Acala and Pima varieties have been managed to take advantage of long growing seasons and high available heat units. With changes in variety regulations, Upland varieties ranging from true early-maturing to medium and late-maturing can be grown if they can fit into a profitable production scheme. In some years, availability and cost of irrigation water and problems with late-season insects and their control costs may provide added incentive to look at alternative varieties or practices that could shorten the duration of growing season needed for cotton in the San Joaquin Valley.

In addition to considering changes in variety choice, growers have options with choices of planting date, plant population, irrigation and growth regulator management. The basis for current recommendations for these management practices for cotton in the San Joaquin Valley region has been reviewed in several publications (Wright *et al.,* 1998; Johnson-Hake *et al*., 1996). Plant population studies conducted in 1996 and 1997 with an Acala variety showed that 100,000 plants ha^{-1} resulted in higher yields than with 150,000 and 200,000 plants ha^{-1} (Wright *et al.*, 1998). In addition, planting date studies conducted in the mid- and late-1990's with the Acala variety "Maxxa" showed that yields decreased 1.5 to 2.0 percent per day with each day after April 20 that planting was delayed (Wright *et al.,* 1998). Recommended irrigation management practices for cotton in California are based upon use of threshold leaf water potentials (LWP) that are related to growth stage, with initial allowable LWP of –1.6 MPa in the period prior to early bloom, followed by a threshold about –1.8 MPa after first bloom and through vegetative cutout (Johnson-Hake *et al.*, 1996). Past studies in California reviewed by Johnson-Hake *et al.* (1996) have shown that irrigation scheduling and imposition of some water stress can strongly influence crop growth, the duration of fruiting, and timing of boll maturity. Similarly, the growth regulator mepiquat chloride (trade name "PIX", others) has been shown in numerous studies to have potential to impact earliness, growth and patterns of fruit retention under some conditions (Kerby *et al.,* 1996). A field study was initiated to investigate impacts of some specific changes in planting dates, plant population, irrigation and growth regulator management on some growth characteristics and yield of an Acala and some more recent non-Acala Upland cottons.

Experimental procedure

The field experiments were set up in 1999, 2000 and 2001 at two locations in the San Joaquin Valley of California (CA): a) West Side site (clay loam soil, western Fresno County, CA; high soil water holding capacity soil with deep rooting possible, good fertility); b) Shafter site (sandy loam soil, northern Kern County, CA; low to moderate soil water holding capacity soil with slow infiltration after mid-season, tendency for compaction problems).

Experiment variables were: a) planting date (early to mid-April versus early May plantings), b) planting density (100,000 versus 185,000 plants/ha), c) varieties (1 Acala and two non-Acala Upland varieties), d) irrigation management (two treatments differing in levels of water stress; and e) two growth regulator treatments (standard University of CA guidelines versus approach that gives guidelines for more within-season applications). Details of treatments are shown in Table 1. Characteristics of the varieties grown are shown in Table 1. The earliest-maturing entry in the trials was changed from Germain's "GC-251" (used in the first year of the trials) to Germain's "GC-204" in years two and three due to changes in available varieties and seed limitations. According to the seed company, these varieties were expected to be quite similar in growth habit and earliness.

Irrigations were scheduled using a leaf pressure chamber, or "pressure bomb" in the first year of the trial, with all leaf water potential (LWP) measurements made during the afternoon from 1300 to 1530 hours. Irrigations were scheduled using –1.6 MPa and –1.8 MPa LWP as target afternoon readings in the non-stressed (NS) treatments during the periods prior to first bloom, and after first bloom, respectively. Irrigations were scheduled in the delayed irrigation (DI) treatment to allow LWP of about –1.75 to –1.8 MPa prior to first bloom, and about –1.95 to –2.0 MPa after first bloom through final irrigation. In the first year of the trial, measurements of leaf canopy temperature were made during the same afternoon period when LWP measurements were made, using an infrared thermometer. An average of six readings was made per plot to get an average canopy temperature. Air temperature and relative humidity at 0.5 m above the crop canopy were also measured with a portable recording thermistor and capacitance humidity sensor, allowing calculation of air vapor pressure deficit. This information was used to calculate crop water stress index and a relationship between LWP and crop water stress index was developed. During the second and third year of the trial, irrigation scheduling decisions were made based on infrared thermometer measurements and crop water stress index values, with 0.075 to 0.125 used as a crop water stress index value to call for irrigation in the non-stressed treatment, versus 0.175 to 0.225 used as a crop water stress index value in the Delayed Irrigation (DI) treatments.

Growth regulator treatments were applications of mepiquat chloride (trade name "PIX Plus") made according to two different protocols: a) application decisions made at close to first bloom (14 to 16 main stem nodes) according to growth regulator guidelines of the University of California (Kerby *et al.*, 1996) which use height:node ratios and square retention in the first five first position fruiting sites or b) the maximum internode distance method, which makes application decisions using length of main stem internodes between the 4th and 5th node down from the terminal (see explanation, Table 1 and in Hutmacher *et al.* (2001). A split plot experimental design was used, with three field replications. Final plant mapping was done on 15 plants per treatment, and all plots were machine-harvested, ginned at our research gin, and sampled for fiber quality HVI analyses.

Results and Discussion

Plant mapping data

Plant mapping measurements were made to assist in explaining the influence of management variables (planting date, density, variety choice, irrigation and growth regulator management) on crop yield responses. Figures 1 and 2 illustrate some of the general responses averaged across all three varieties. Some generalizations were that later planting dates (May versus April) resulted in taller plants, with fewer fruiting branches and reduced bolls per plant. Some of these results may be related to the fact that later plantings develop during warmer weather, resulting in faster vegetative growth, but with less total developmental time, fruit production can be reduced. Higher plant populations tended to produce taller plants with fewer total bolls and fruiting branches (more competition between plants for limited resources). Delayed irrigations (DI treatments as identified in Figures 1 and 2) resulted in plants that were slightly shorter, with slight reductions in average bolls per plant and number of fruiting branches when compared with non-stressed (NS) plants (Figures 1 and 2). The earliest-maturing varieties were the short-season Upland "GC-204/251", followed by "NuCOTN 33B". The Acala variety "Maxxa" was the latest-maturing. Total fruiting branch number was proportional to earliness, but average number of bolls per plant was much higher on both of the smaller-boll size non-Acala Uplands.

The two sites differed in responses to management practices and therefore in growth habit for several reasons. Early fruit retention was exceedingly high at the West Side site in 1999 and 2001 (over 90% in the first position fruit in the first 8-9 fruiting branches), while the fruit retention was typically lower at the Shafter site (less than 40% in first position fruit in the first seven fruiting branches in 1999, about 60 percent other years). Early fruit loss tended to promote larger leaf areas and more vegetative branch development in the mid-season bloom period, particularly in both non-Acala Upland varieties (data not shown). Plant growth and development at the Shafter site was also more non-uniform across field replications than at the West Side REC location due to the presence of variable soil texture within the plot areas at Shafter. These non-uniform soil conditions impacted responses to irrigation treatments and also impacted the relative need for plant growth regulators. Growth regulator impacts on yields were quite variable across varieties and treatments and will only be briefly discussed in this paper.

Yield responses to management variables

Yield responses to planting date and plant population differences are shown separately for each of the three varieties in Figures 3, 4 and 5 (West Side site) and Figures 6, 7 and 8 (Shafter site). Differences among varieties were seen in the degree of planting date and density effects on yield. Benefits of the earlier (April) planting dates over early May planting dates were quite consistent, and were observed most years in both sites and with all three varieties.

There are some generalizations that can be made across locations, and some differences noted across locations in the 2000 data. In the year 2000 at the Shafter site, April plantings had lower yields than May plantings, and this was due to heavier early-season fruit losses. Field measurements and insect scouting indicated that *Lygus* populations were high at some critical early stages of square formation in the April plantings. *Lygus* control measures were initiated, and pest populations were reduced later on, resulting in less yield impact on the later (May) plantings. This effect would have been less likely to achieve if the late summer and early fall weather of 2000 had not been as favorable (which allowed full maturation of the May-planted crop). Nevertheless, this data points out the ability of the cotton plant to compensate for early yield losses if later pest pressure and weather "cooperate" and give adequate time to mature a later crop.

Situations where yield improvements with the earlier (April) planting date were numerically greatest were: 1) with longer season varieties such as Maxxa and NuCOTN 33B; 2) when fall weather conditions were cooler; and 3) under high yield conditions at the West Side site. Reductions in lint yield at the higher plant population (185,000 plants/ha) were generally greater in the Acala variety "Maxxa" than in either of the non-Acala varieties. Plant population effects on lint yield were less consistent than those observed in prior University of CA studies (Wright *et al.*, 1998), which were all done on an Acala variety, and generally showed peak yields at about 100,000 plants/ha with significant yield reductions at higher populations. In the non-Acala Uplands, higher populations tended to reduce yields most with earlier planting dates under high yield conditions. Higher populations gave similar or slightly better yields generally under lower vigor, lower yield conditions and with later planting dates (Figures 6, 7 and 8). Differences in yield impacts of treatments were quite pronounced between the two locations and some results differed across years. In 1999 and 2001, the most consistent yield improvements were with the earlier planting dates, with planting densities approximately 100,000 plants per ha instead of 185,000, and with earlier irrigation termination and more water stress in the DI irrigation treatment. The varieties (Maxxa versus the two CA Uplands) were quite consistent in the relative response to different irrigation, planting date and density treatments, although the magnitude of the responses differed (ie. slightly less negative impact of higher plant density or delayed planting on the CA Uplands than on the Acala variety).

Delayed irrigation (DI) treatments resulted in leaf water potentials that were 0.15 to 0.20 MPa lower than in non-stressed (NS) treatments (data not shown). Delayed irrigation treatments often resulted in slightly higher lint yields in both non-Acala Upland varieties (sometimes significantly higher). In the Acala variety, delayed irrigation treatments usually resulted in either no significant impact on yields, or under conditions of high early fruit retention, slight reductions in lint yield.

Analyses of the lint yield responses to two growth regulator management practices were evaluated, and some generalizations can be made. One growth regulator management approach used standard Acala Guidelines for mepiquat chloride (MC) management (Kerby *et al.*, 1996) that were developed from plant height, node number and fruit retention near first bloom data regressed against lint yield responses. For comparison, the Maximum Internode Distance method (MID) approach (described in Hutmacher *et al*. (2001)) uses guidelines for application made as early as 9-10 main stem nodes, with multiple applications possible all the way through 19-20 nodes. In about two-thirds of the management practice treatment combinations (planting date, density and irrigation), a one-time MC application made using the Acala growth regulator guidelines produced similar or slightly higher yields than with the MID approach with multiple applications (data not shown). The best responses to the MID approach, which allows earlier and more PIX applications, was with delayed plantings and higher plant densities, and in fields (such as Shafter in 1999) where early and mid-season fruit retention was variable and low (data not shown).

Impacts on fiber quality parameters

Data in Figures 9 to 11 represent only part of total years / sites, but some generalizations are apparent. Later planting dates and higher density plantings both tended to significantly decrease fiber micronaire. Varietal differences in average micronaire values were large, but patterns of influence of planting dates and densities were similar across varieties. Fiber strength was slightly higher in earlier planting dates, but plant populations did not have a consistent impact on strength (Figure 10). Measurements that provide some indication of leaf or trash were highly variable with variety and year, but were consistent in showing higher values with higher plant populations (Figure 11). Most other primary fiber quality parameters (length, uniformity, color grade, uniformity) were less affected by planting date or population than micronaire, strength or some measure of leaf or trash. Some details of treatment effects on fiber quality will not be presented in this paper due to space limitations, but in general planting date, plant density, irrigation treatment and PIX treatments had less impact on measured fiber quality characteristics (length, strength, micronaire, leaf grade) than did variety. Irrigation treatments that differed by only about 0.2 MPa leaf water potential, for instance, were generally not stressed severe enough to impact fiber length, strength or micronaire, although relatively minor impacts were noted (data not shown). Variety choice and to a secondary degree, planting date and planting density had more of an impact on fiber quality characteristics in the combination of treatments most likely to impact fiber development (such as late planting, more stress and higher planting density (data not shown).

Conclusions

Benefits of April planting dates over early May planting dates were quite consistent, and were observed most years in both sites, with all three varieties in the tests. Situations where yield improvements with the earlier (April) planting date were numerically greatest: 1) with longer season varieties such as Maxxa and NuCOTN 33B; 2) when fall weather conditions were cooler; and 3) under high yield conditions exemplified by the West Side (clay loam site), with lower relative yield differences under lower yield conditions at Shafter (sandy loam site). Planting density / population effects on lint yields: 1) were less consistent than observed in prior University of CA studies done on Acala varieties in the San Joaquin Valley; 2) the higher density tended to reduce yields mostly with earlier planting dates at the higher yield location; and 3) higher density plantings gave similar or slightly better yields under lower yield potential conditions (sandy loam soil) or with later (May) plantings. Variations between varieties were seen in the degree of planting date and density effects on lint yield. Reductions in lint yield at the higher planting density were generally greater in the Acala variety (Maxxa) than in either non-Acala variety.

References

- Hutmacher, R.B., Delgado, R.L., Keeley, M.P., Marsh, B.H., Perkins, S., Weir, E. and Sanchez, L. (2001). Maximum Internode Distance (MID) method for mepiquat chloride decisions: California Evaluations. *Proceedings Beltwide Cotton Conference*, **1**: 527-530.
- Johnson-Hake, S., Hake, K.D., Kerby, T.A. (1996). Planting and Stand Establishment. *In Cotton Production Manual*. S. Johnson-Hake, T.A. Kerby, K.D. Hake (eds.). University of CA Division of Agriculture and Natural Resources Public. 3352, Ch. 4, pp. 21-29.
- Johnson-Hake, S., Grimes, D.W., Hake, K.D., Kerby, T.A., Munier, D.J. and Zelinski, L.J. (1996). Irrigation Scheduling. *In* Cotton Production Manual. S. Johnson-Hake, T.A. Kerby, K.D. Hake (eds.). University of CA Division of Agriculture and Natural Resources Public. 3352, Ch. 18, pp. 228-247.
- Kerby, T.A., Weir, B.L. and Keeley, M.P. (1996). The Uses of PIX. *In* Cotton Production Manual. S. Johnson-Hake, T.A. Kerby, K.D. Hake (eds.). University of CA Division of Agriculture and Natural Resources Public. 3352, Ch. 21, pp. 294-304.
- Wright, S.D., Vargas, R., Weir, B., Munk, D., Roberts, B.A., Hutmacher, B., Martin-Duvall, T.M., Keeley, M.P., Banuelos, G. and Jiminez, M.R. (1998). Effect of Planting Date and Density on San Joaquin Valley Cotton. *Proceedings Beltwide Cotton Conference,* **2**: 1450-1451.

Table 1. *Treatment descriptions in Upland cotton management studies (1999-2001).*

Variables	Treatments		
Varieties (3 varieties used)	Maxxa (CPCSD, Approved Acala, high fiber quality, full-season growth habit)	NuCOTN 33B (Delta Pine, non-Acala Upland, mid- to full-season variety)	GC-204 & GC-251 (Germains, non-Acala Upland, early to mid-season)
Planting dates (2 dates used)	Early to mid-April (varied with location and year)	Early May (planting dates varied with location and year)	
Plant population (2 populations used)	100,000 plants per hectare	185,000 plants per hectare	
Irrigation management (2 approaches used)	Non-stressed (NS) University of California Acala guidelines based on leaf water potential measurements	Delayed Irrigation (DI) Delayed irrigations based on delayed irrigations from the second through final irrigation of the growing season (see "Experimental Procedures" section for details)	
Growth regulator management (2 approaches used)	Acala Management Guidelines Growth regulator decisions based on height:node and fruit retention measurements near time of first flower	Maximum Internode Distance Method Application decisions made based on length of main stem internode between the 4^{th} and 5^{th} node down from the terminal. Decisions on applications made using this method multiple times between the time plants have 9 through about 20 main stem nodes.	

Figure 1.
Impacts of planting date and density, irrigation management and variety on plant height at the time of Final Plant Mapping (Sept. 2001) at the West Side site.

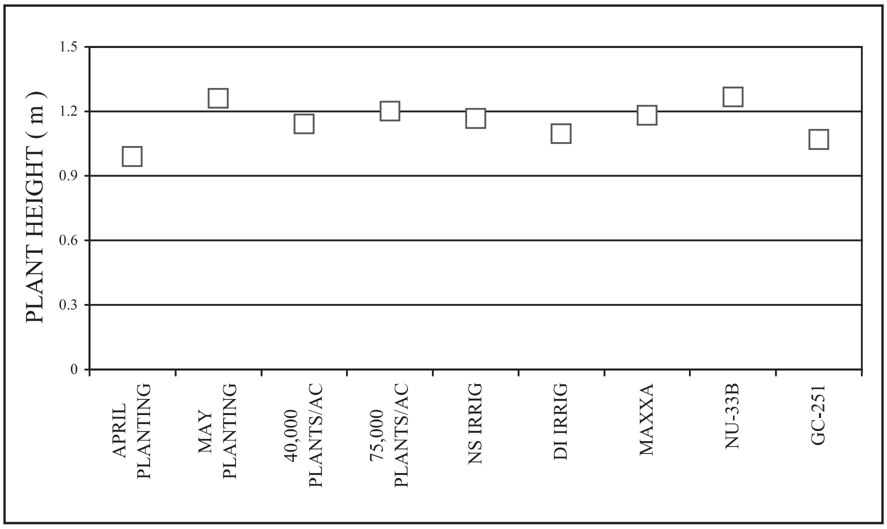


Figure 2.
Impacts of planting date (April, May), planting density (100,000 versus 185,000 plants per ha), irrigation management (non-stressed (NS) and delayed irrigation (DI)) and variety on specific plant parameters. Parameters shown include number of fruiting branches (fb) with harvestable bolls; number of vegetative nodes; number of bolls per plant; and number of fruiting branches in the 95% zone at the time of Final Plant Mapping (Sept. 2001) at the West Side site.

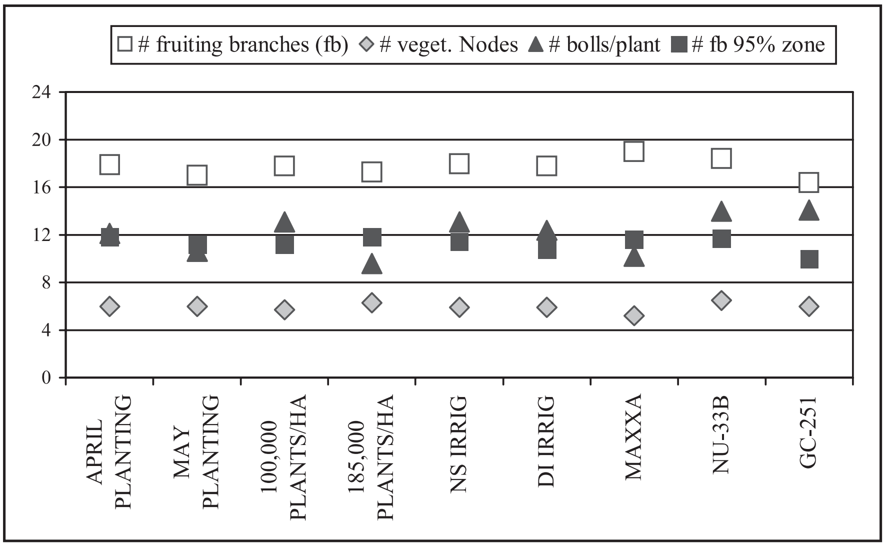


Figure 3. *Planting date (April, May), density (100,000 versus 185,000 plants per ha), and irrigation treatments (NS, DI) impacts on lint yield (variety GC-251 (1999) and GC-204 (2000, 2001)) at the West Side site, averaged across all varieties and treatments.*

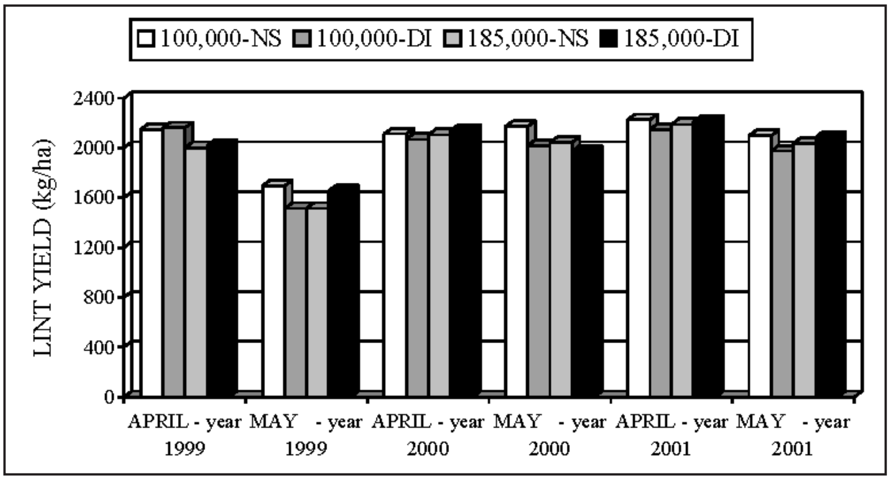


Figure 4. *Planting date (April, May), density (100,000 versus 185,000 plants per ha), and irrigation treatments (NS, DI) impacts on lint yield (variety Maxxa) at the West Side site, averaged across all varieties and treatments.*

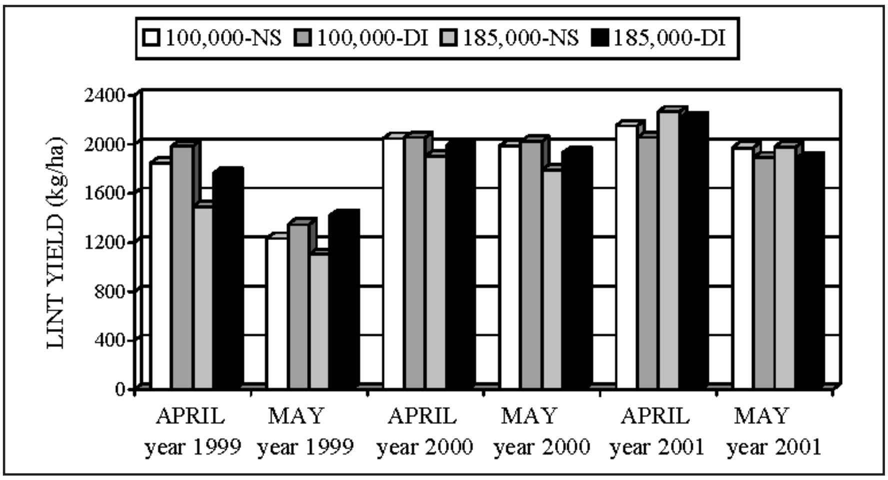
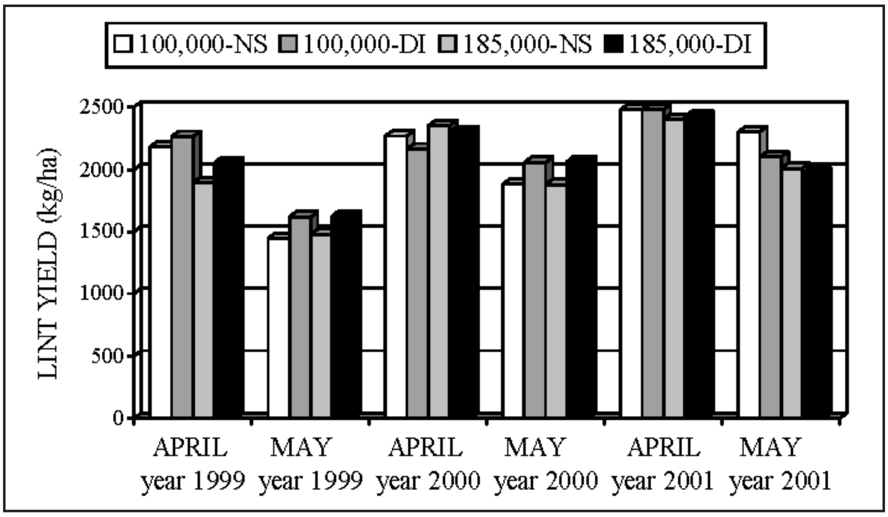


Figure 5. *Planting date (April, May), density (100,000 versus 185,000 plants per ha), and irrigation treatments (NS, DI) impacts on lint yield (variety NuCOTN 33B) at the West Side site, averaged across all varieties and treatments.*



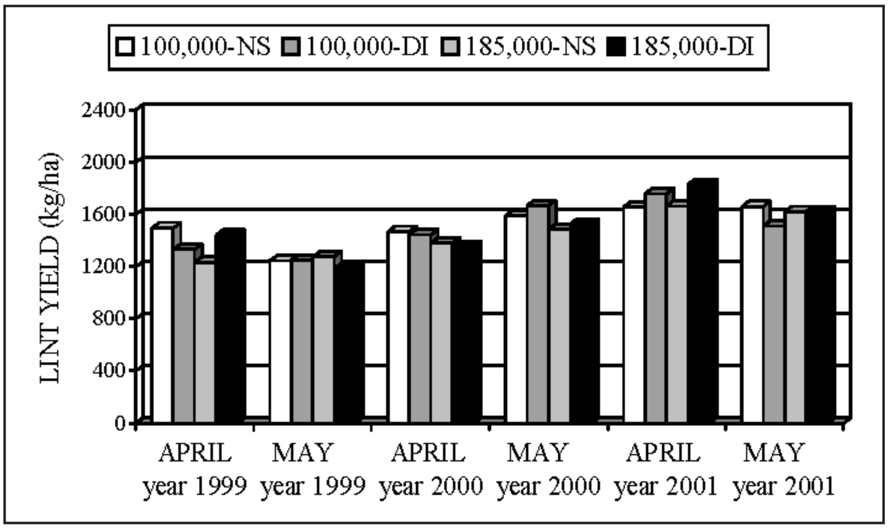


Figure 6. *Planting date (April, May), plant density (100,000 versus 185,000 plants per ha) and irrigation treatment (NS, DI) impacts on lint yield (variety Maxxa) at the Shafter site, averaged across all varieties and treatments.*

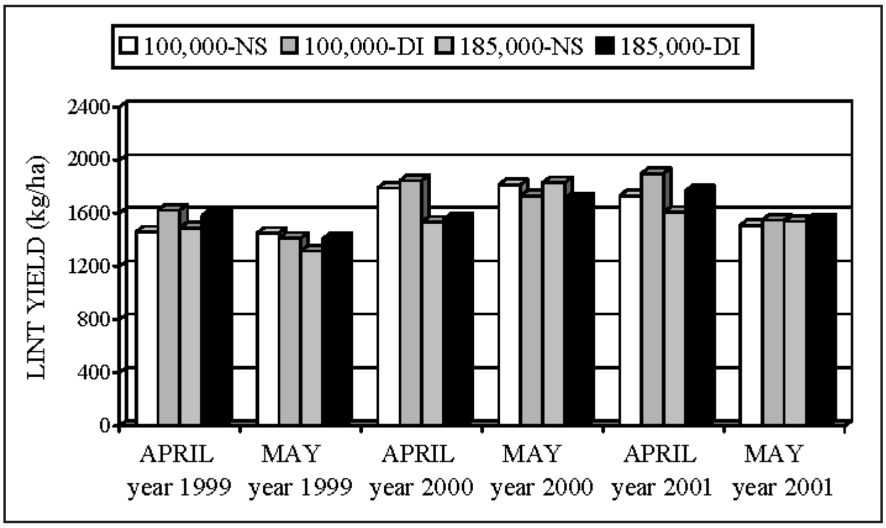


Figure 7. *Planting date (April, May), density (100,000 versus 185,000 plants per ha) and irrigation treatment (NS, DI) impacts on lint yield (variety GC-251 (1999) and GC-204 (2000, 2001)) at the Shafter site, averaged across all varieties and treatments.*

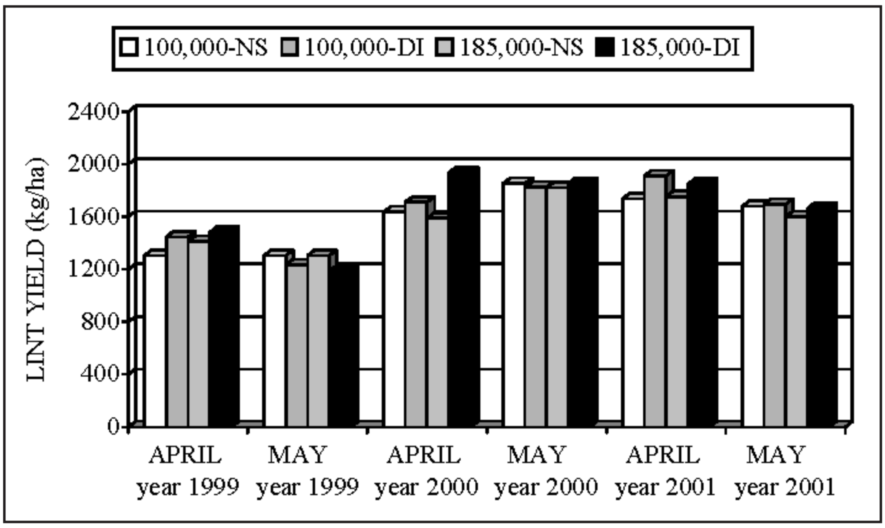


Figure 8. *Planting date (April, May), density (100,000 versus 185,000 plants per ha) and irrigation treatment (NS, DI) impacts on lint yield (variety NuCOTN 33B) at the Shafter site, averaged across all varieties and treatments.*

Figure 9.
Planting date and density impacts on fiber micronaire, averaged across all varieties and treatments for the years shown at the West Side (WS) and Shafter (SH) sites. Average micronaire values for each variety across all treatments were as follows: Maxxa = 4.27; GC-204/251 = 4.91; NuCOTN 33B = 4.30.

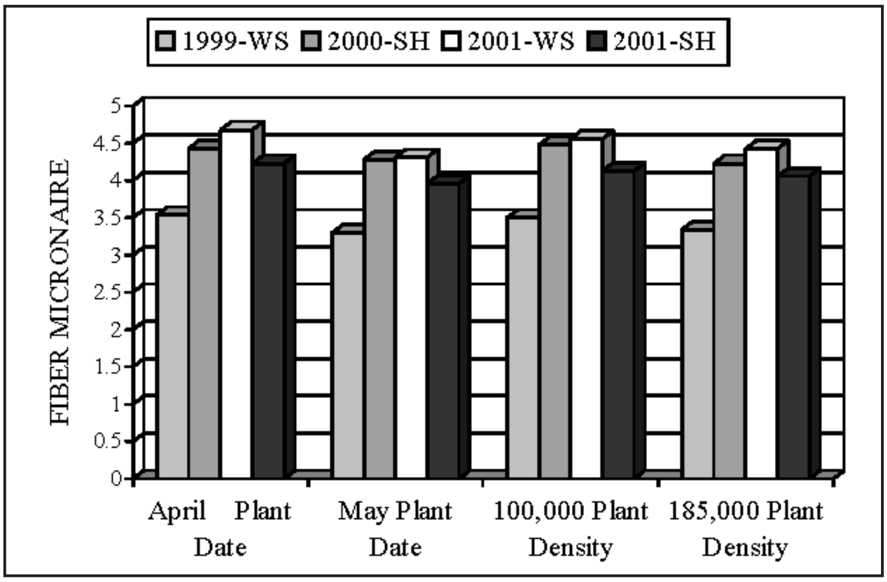


Figure 10.
Planting date and density impacts on fiber strength, averaged across all varieties and treatments for the years shown at the West Side (WS) and Shafter (SH) sites. Average fiber strength values for each variety across all treatments were as follows: Maxxa = 33.4; GC-204/251 = 31.1; NuCOTN 33B = 29.7.

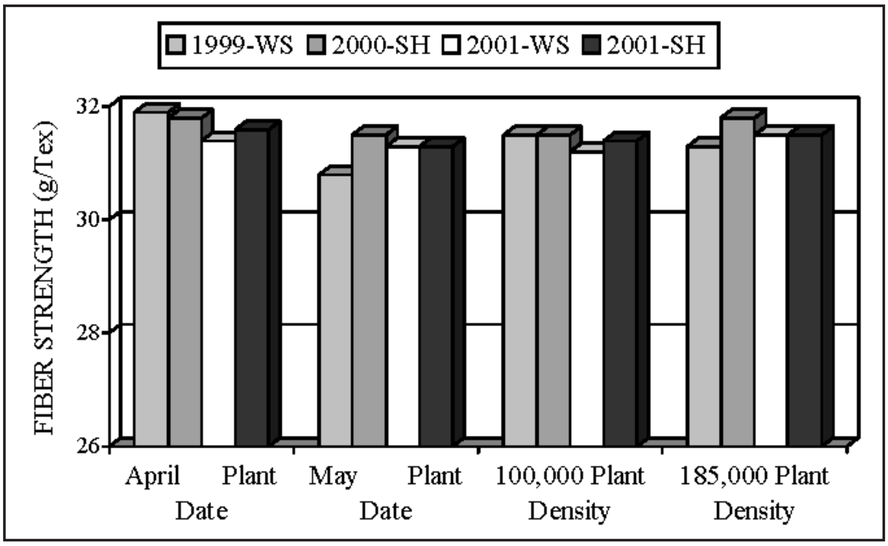


Figure 11.
Planting date and density impacts on leaf grade, averaged across all varieties and treatments for the years shown at the West Side (WS) and Shafter (SH) sites. Average leaf grade values for each variety across all treatments were as follows: Maxxa = 3.0; GC-204/251 = 2.4; NuCOTN 33B = 2.1.