Evaluation of Irrigation Termination Effects on Fiber Micronaire and Yield of Upland Cotton, 2000

J.C. Silvertooth, A. Galadima, E.R. Norton, and H. Moser

Abstract

Arizona has experienced a trend toward increasing fiber micronaire values in recent years resulting in substantial discounts on fiber value. There is some evidence to suggest that irrigation termination management can impact fiber micronaire. A single field study was conducted in 2000 at the Maricopa Agricultural Center (1,175ft. elevation) to evaluate the effects of three dates of irrigation termination on the yield of 13 Upland cotton varieties. Planting date was 6 April (668 HU/Jan 1 86/55^o F thresholds). Three dates of irrigation termination (IT1, IT2, and IT3) were imposed based upon crop development into cutout. The earliest irrigation termination date, IT1 (24 July) was made slightly ahead of an optimum date to provide sufficient soil-water such that bolls set at the end of the first fruiting cycle would not be water stressed and could be fully matured. Thus, the IT1 date was imposed to try to reduce overall micronaire. The second termination (IT2) date was 17 August, and provided one additional irrigation over an optimal point for the first cycle fruit set and two irrigations beyond IT1. The final (IT3) date was 15 September, which was staged so that soil moisture would be sufficient for the development of bolls set up through the last week of September thus providing full top-crop potential. Lint yield and micronaire results revealed significant differences among the IT treatments. Micronaire and lint yield values increased with later IT dates.

Introduction

One of the advantages associated with a cotton (*Gossypium spp*.) production system in an irrigated desert region such as Arizona, is the availability of a relatively long growing season, or a reliable supply of abundant heat units (HU). Traditionally, cotton production systems in the low (elevation) desert regions of Arizona (<2,000 ft. above sea level) have employed a long, full season approach. Such a long, full season approach would commonly involve a February or March date of planting with final irrigations being applied in September or October (depending on local conditions). Production over this period would include a completion of the first, or primary fruiting cycle, a cutout period (hiatus in blooming), followed by a second fruiting cycle or top-crop. Accordingly, long season, indeterminate varieties were usually best suited to this type of production system. This is one of the reasons that Pima (*G. barbadense* L.) has been well adapted to this region.

Overall, the objective with a reduced season approach to cotton production in the irrigated southwest is to achieve the highest degree of efficiency possible. To do so requires an identification of the point of diminishing returns with respect to a cotton crop. This is based on the assumption that yield potentials decline with time in the later stages of the growing season due to natural crop senescence, shorter day lengths, and cooler weather conditions (lower rates of HU accumulations).

Recent research in Arizona has attempted to address this issue by comparing a reduced season approach to that of a more traditional long, or full season system (Silvertooth et al., 1989; Silvertooth et al., 1990; Silvertooth et al., 1991; Silvertooth et al., 1992; and Silvertooth et al., 1993; Silvertooth et al., 1994; Unruh et al., 1995; Silvertooth and Norton, 1996; and Silvertooth and Norton, 1997). Summarizing this work, Unruh and Silvertooth (1997) reported on 12 site-

This is part of 2001 Arizona Cotton Report, The University of Arizona College of Agriculture and Life Sciences, index at http://ag.arizona.edu/pubs/crops/az1224/

years of data in Arizona comparing various planting and irrigation termination date combinations. The overall results from these studies revealed a most pronounced improvement in yield from an early date of planting and a generally small increase in yield from a late irrigation termination date. Comparing early and late IT treatments with an early date of planting, Unruh and Silvertooth (1997) found an average increase of 83 and 118 lbs. of lint/acre for DPL 90 and Pima S-6, respectively. Large increases in lint yield from a later IT were observed in a few experiments, but usually under conditions of very poor fruit retention over the primary fruiting cycle (up to cut-out).

About 600 HU (86/55 ^{o} F thresholds) are required to develop a late season boll from a bloom to a full sized, hard boll when fiber length development is complete (Silvertooth et al., 1996). Approximately 400 additional HU are then required to complete boll maturation and opening, for a total of 1,000 HUs needed for boll development from bloom to open boll. Therefore, IT treatments are best structured to accommodate development of bolls intended for harvest to the point of full fiber development (600 HU post-anthesis). This commonly translates to a period of approximately 21 days in southern Arizona in August and September. Accordingly, adequate soil moisture must be maintained throughout this three-week period for the last set of bolls intended for harvest. The exact IT date will therefore vary depending upon soil water holding capacities, amounts of water applied per irrigation, weather conditions, and crop condition. For example, if bolls set up to the point of cut-out are designated as those intended for harvest, final irrigations should be made so that adequate soil moisture is maintained for a three week (600 HU) period beyond the time of cut-out. The development of a top-crop usually requires irrigation and pest control for four to six weeks beyond cut-out, which for many systems equates to approximately an extra acre-foot of irrigation water and appropriate pest control to protect the developing fruit load.

In recent years an increasing percentage of the Arizona cotton crop has been classified with micronaire (mic) ranges in excess of 4.9, resulting in a discount of the market value of the fiber. In 1999, slightly over 40% of the Arizona Upland cotton crop was classed with mic values greater than 4.9. For example, Group 6 mic values (5.0-5.2) can result in $0.05/lb. discounts and Group 7 ($\geq$5.3) $0.10/lb. discounts. With low market values of cotton lint, as have been experienced recently (i.e. ~ $0.50/lb.), discounts of this magnitude can have a devastating impact on farm revenues. Some economists have estimated that this problem has resulted in a loss of revenue to the Arizona cotton producers of approximately $13 to 15 million per year in the past several years. However, some cotton marketing professionals in Arizona have indicated that they believe these losses in revenue due to high micronaire are in the range of $20 to 25 million per year over the past four to five years. Thus, high micronaire is reducing the profitability of Arizona cotton production at this time.

Strategies to reduce micronaire in Arizona must consider three primary factors: 1) genetics, 2) environment, and 3) management. These three factors form a complex set of effects and interactions that determine the micronaire of a crop. The degree of genetic influence on micronaire depends on the different types of varieties that are adapted to the region of influence and the range of environmental conditions within that region. The statement is often made that "only 30% of the cotton micronaire properties are determined by genetics (variety) with 70% determined by agronomic management ". University of Arizona variety trial data from 1996 through 1999 indicate that about 20% of the variation in micronaire in central Arizona was due to the genetic control of the varieties in those tests. In comparison, variation due to varieties was 50% for fiber strength, 36% for fiber length and 17% for lint yield. These data show that the environment and management exert more influence on micronaire than other fiber properties, so no matter what variety is chosen, growers can, and probably will, see wide variations in micronaire values from field to field and year to year. There remains a strong genetic component, however, the average micronaire can be reduced through proper varietal selection.

The relationship between varieties and micronaire is also complicated by the fact that high yield is genetically related to high micronaire. With our current genetic resources, the higher yielding varieties also tend to produce higher micronaire as well. This relationship between yield and micronaire is probably a strong contributing factor to the trends we have observed in micronaire over the last few years. . In Arizona, we have seen a slight increase in average mic values in the early 1990's (~1993) and again in about 1996. A similar trend is apparent with data from the entire U.S. cotton belt. Also, in review of the mic distributions among all cotton producing regions in the U.S., there is a somewhat normal distribution pattern with a peak mic value at approximately 4.9-5.0 and distinct drop above 5.0. These two points support the hypothesis that there is a strong genetic component associated with recent trends in Arizona and U.S. mic values and that varieties have been developed to "push" the mic limits (i.e. 5.0).

There is also ample evidence to support the position that Arizona, particularly the low elevation locations (< 2,000 ft.), has a hot environment that is conducive to high micronaire production (hot conditions for both day and night temperatures). Thus, it appears that in Arizona we are producing a cotton crop in an environment that is conducive to high mic production with varieties that, as a whole, have a tendency toward high mic as well. The relationships associated with high mic and the third primary component (management) is not well understood in the context of desert cotton production.

Based on an analysis of data from several cotton growing areas in Arizona, it appears that there is indeed a relationship associated with location and variety and fiber mic. From this data there also appears to be a relationship between fiber mic and management, in that certain growers within given areas tend to have a very high percentage of their crop classed with high mic and another set of growers in the same area have a very low percentage of their crop with low mic using basically the same group of varieties.

There is evidence from earlier studies conducted in Arizona (Silvertooth et al., 1989; Silvertooth et al., 1990; Silvertooth et al., 1991; Silvertooth et al., 1992; and Silvertooth et al., 1993; Silvertooth et al., 1994; Unruh et al., 1995; Silvertooth and Norton, 1996; and Silvertooth and Norton, 1997) to study the effects of irrigation termination (IT) on yield and quality to suggest that IT and/or defoliation can have a significant impact on fiber mic.

It is the purpose of this research project to better delineate the contributions associated with genetics, environment, and management on fiber micronaire. The objective of this study was to further investigate the issue of IT management and the subsequent effects on the growth, development, yield, and micronaire of a group of common Upland (*G. hirsutum* L.) varieties.

Methods and Materials

This study was conducted in 2000 at the Maricopa Agricultural Center (1,175 ft.) on a Casa Grande sandy loam soil. The experimental design was a split plot in a randomized complete block design with four replications. The main treatments consisted of three IT dates, designated as IT1, IT2, and IT3. Each main plot consisted of 12, 40-inch rows that extended the full length of the irrigation run (600 ft.). The subunits consisted of 13 Upland varieties. Subplots were 12, 40-inch rows wide and 40 feet in length. The entire study area was dry planted and watered-up on 6 April 2000. All inputs such as fertilizer, water, and pest control were managed on an as-needed basis.

A complete set of plant measurements were collected from all plots on 14-day intervals. Measurements taken included: plant height, number of mainstem nodes, first fruiting branch, total number of aborted sites (positions 1 & 2), number of nodes above the top (1st position) fresh flower (NAWF), canopy closure, and number of blooms per unit area. Climatic conditions were also monitored using an Arizona Meteorological network (AZMET) site located on the station.

Irrigation termination treatments were imposed in relation to the crop fruiting cycle in a manner similar to that described in Figure 1. In tracking crop development, the crop was approaching cut-out, normally considered as having NAWF ≤ 5, as evidenced by an average NAWF ~ 6 among all varieties. The first IT treatment (IT1) was made on 25 July with the intention of terminating irrigations somewhat pre-maturely. Based upon current UA recommendations for IT to complete a single cycle fruit set, the more optimal date of IT would have been about 5 August. In this experiment, IT2 was structured to provide an additional (one) irrigation beyond the more optimal date. In this case, IT2 was made on 17 August. For the IT3 plots the intention was to attempt a second cycle fruit set and irrigations were continued until 15 September. The IT2 treatment received two additional irrigations over IT1 and IT3 received four additional irrigations over IT1 (approximately two acre-feet of additional irrigation water).

The IT1 plots were defoliated on 29 August and picked by use of a two row mechanical picker on 13 September. The IT2 plots were defoliated on 13 September and harvested on 4 October. The IT3 plots were defoliated on 12 October and harvested on 5 December. The IT3 plots received nearly 2.0 inches of rain and an early freeze in late October which made defoliation more difficult and delayed harvest. Only the center four rows of each 12-row plot were harvested.

Approximately 20 lb. seed cotton subsamples were collected from each plot at harvest. These subsamples were ginned for turnout estimates and submitted to the USDA Cotton Classing office in Phoenix, AZ for HVI analysis. All mic and lint yield data were subjected to appropriate analysis of variance procedures.

Results

Micronaire results are presented in Tables 2-4 and Figures 2 and 3. There were significant main effects due to IT and variety and the interaction term was not significant (Tables 2 and 3). The coefficients of variation (CV) were < 9% in all cases. Average mic values were lowest for IT1 and generally increased with later IT dates. Mean mic values for IT1 were below 5.0 and significantly lower than those for IT2 and 3 (both > 5.0).

Lint yield results are summarized in Tables 5-7 and Figures 3 and 4. In the case of lint yield both main effects and the interaction terms were all significant ($P \leq 0.05$). Lint yield patterns were very similar to mic as a function of IT. Lint yields increased with later IT. The IT1 lint yield means were significantly lower than yields for IT2 and 3. For example, mean lint yields among all varieties was ~ 1300 lbs. lint/acre for IT1 and nearly 1800 lbs. lint/acre for IT3.

In this experiment, the IT3 treatments did provide for the development of a top-crop (second fruiting cycle) that enhanced yield. However, the additional bolls developed from the top-crop did not reduce the overall fiber mic in relation to either IT2 or IT1. From this experiment one might conclude that IT is a feasible means of managing fiber mic. In this case, it was possible to maintain mic values below the 5.0 discount range on fiber value due to high mic. However, that objective would have to be considered in relation to the benefits associated with increasing lint yield. Therefore, mic discounts, the cost of producing a top-crop, and potential yield benefits must be considered together in developing a management strategy for optimum economic returns.

These results are consistent with earlier work on this topic (Silvertooth et al., 1989; Silvertooth et al., 1990; Silvertooth et al., 1991; Silvertooth et al., 1992; and Silvertooth et al., 1993; Silvertooth et al., 1994; Unruh et al., 1995).

Acknowledgements

The financial support provided by the Arizona Cotton Growers Association and Cotton Inc., Anderson Clayton Company, and Hanwerker-Winburne is greatly appreciated. We gratefully acknowledge the excellent assistance from the personnel at the Maricopa Agricultural Center. Also the hard work and technical assistance provided by the research assistants with the UA Cotton Agronomy program is greatly appreciated.

References

Silvertooth J. C., J. E. Malcuit, D. R. Howell and P. Else. 1989. Effect of date of planting on the lint yield of several cotton varieties planted at four locations in Arizona, 1988. p. 69-72. Cotton, Univ. of Arizona Rep. P-77.

Silvertooth J. C., T. F. Watson, J. E. Malcuit, and P. W. Brown. 1992. Evaluation of date of planting and irrigation termination in the yield of Upland and Pima cotton. p. 252-273. Cotton, Univ. of Arizona Rep. P-91.

Silvertooth J. C., T. F. Watson, J. E. Malcuit, and P. W. Brown. 1993. Evaluation of date of planting and irrigation termination in the yield of Upland and Pima cotton. p. 27-39. Cotton, Univ. of Arizona Rep. P-94.

Silvertooth J. C., T. F. Watson, L. I. Terry, and J. E. Malcuit. 1990. Evaluation of date of planting and irrigation termination in the yield of Upland and Pima cotton. p. 6-12. Cotton, Univ. of Arizona Rep. P-81.

Silvertooth J. C., T. F. Watson, L. I. Terry, and J. E. Malcuit. 1991. Evaluation of date of planting and irrigation termination in the yield of Upland and Pima cotton. p. 1-14. Cotton, Univ. of Arizona Rep. P-87.

Silvertooth, J.C., and E.R. Norton. 1996. Evaluation of irrigation termination management on yield of upland cotton, 1995. p. 40-45. Cotton, Univ. of Arizona Rep. P-103.

Silvertooth, J.C., and E.R. Norton. 1997. Evaluation of irrigation termination management on yield of upland cotton, 1996. p. 218-224. Cotton, Univ. of Arizona Rep. P-108.

Silvertooth, J.C., E.R. Norton, and P.W. Brown. 1996. Cotton growth and development patterns. p. 75-97. Cotton, Univ. of Arizona Rep. P-103.

Unruh, B.L., J.C. Silvertooth, P.W. Brown, and E.R. Norton. 1995. Effect of planting date on yield of Upland and Pima cotton varieties at Marana. p. 20-24. Cotton, Univ. of Arizona Rep. P-96.

Unruh, B.L. and J.C. Silvertooth. 1997. Planting and irrigation termination timing effects on the yield of Upland and Pima cotton. J. Prod. Agric. 10:74-97.

Fig. 1. General irrigation termination points in relation to the fruiting cycle.

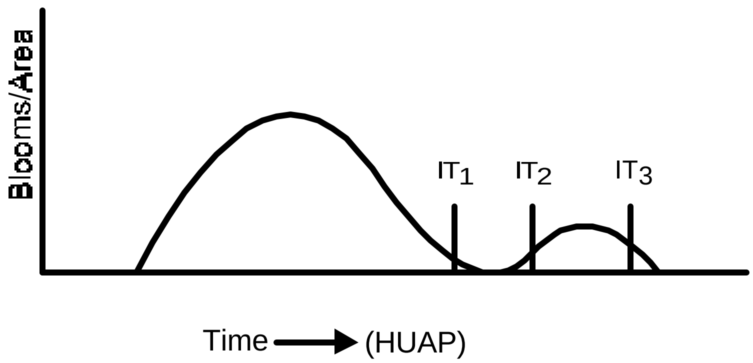

Table 1. Irrigation termination dates and varieties, irrigation termination dates by variety study, Maricopa, AZ, 2000 (6 April planting and water-up).

Varieties	**Maturity Type**
BXN47	Medium
DP428B	Short-medium
DP422BR	Short
DP33B	Full
DP20B	Early
DP388	Medium
STV474	Medium
STV4691B	Medium
SG125BR	Short
SG747	medium
DP655BR	Full
DP451BR	medium
DP5415	Full
Irrigation Termination Dates	
Date 1 (25 July)	(3162 HU/Jan. 1)
Date 2 (17 August)	(3765 HU/Jan. 1)
Date 3 (15 September)	(4623 HU/Jan. 1)

Table 2. Experimental effects and statistical significance from the analysis of variance on micronaire, irrigation termination by variety study, Maricopa, 2000.

Source of Variation (Effect)	**OSL (Pr >F)**
Irrigation Termination Date	0.0032
Variety	0.0012
Irrigation Termination Date * Variety	0.5247

Table 3. Main effect results of micronaire for irrigation termination dates and varieties, Maricopa, AZ, 2000.

Irrigation Termination Date	**Micronaire**
1	4.58 b*
2	5.23 a
3	5.18 a
LSD	0.16
OSL**	0.0032
CV(%)§	6.99
Variety	
DP655BR	5.32 a
DP5415	5.20 ab
DP422BR	5.17 ab
DP33B	5.17 ab
DP388	5.13 ab
BXN47	5.12 abc
DP451BR	5.02 abc
ST474	4.97 abc
DP428B	4.93 abcd
ST4691B	4.82 bcd
SG747	4.81 bcd
DP20B	4.73 cd
SG125BR	4.54 d
LSD	0.40
OSL	0.0012
CV(%)	8.6

*Least Significant Difference – means followed by the same letter are not significantly different according to a Fishers mean separation test at 0.05 level.
**Observed Significance Level.
§Coefficient of Variation

Table 4. Micronaire results by variety for each irrigation termination date, Maricopa, AZ, 2000.

Irrigation Termination Date	**BXN 47**	**DP 20B**	**DP 33B**	**DP 388**	**DP 422BR**	**DP 428B**	**DP 451BR**	**DP 5415**	**DP 655BR**	**SG 125BR**	**SG 747**	**STV 4691B**	**STV 474**
1	4.70	4.10	4.80	4.87	4.53	4.53	4.77	4.97	5.07	4.17	4.13	4.47	4.43
2	5.27	5.00	5.33	5.13	5.53	5.13	5.17	5.43	5.50	4.83	5.20	5.13	5.17
3	5.40	5.10	5.37	5.40	5.43	5.13	5.13	5.20	5.40	4.63	5.10	4.87	5.30

Table 5. Experimental effects and statistical significance from the analysis of variance on lint yield, irrigation termination by variety, Maricopa, 2000.

Source of Variation (Effect)	**OSL (Pr >F)**
Irrigation Termination Date	0.0272
Variety	0.0529
Irrigation Termination Date * Variety	0.0452

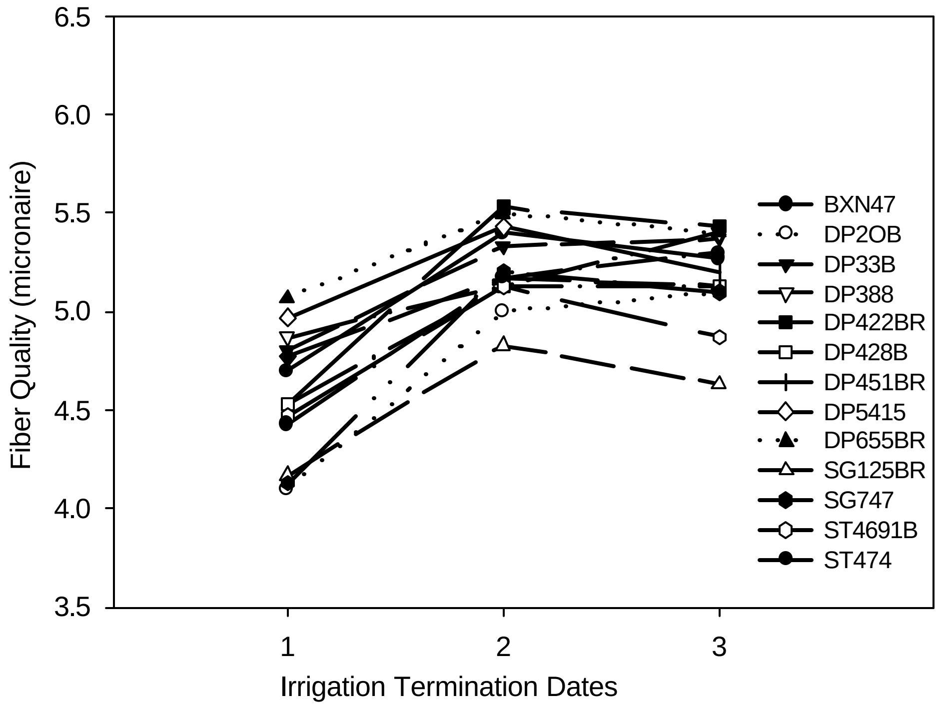

Fig. 2. Micronaire values as affected by irrigation termination date for each variety, Maricopa, 2000.

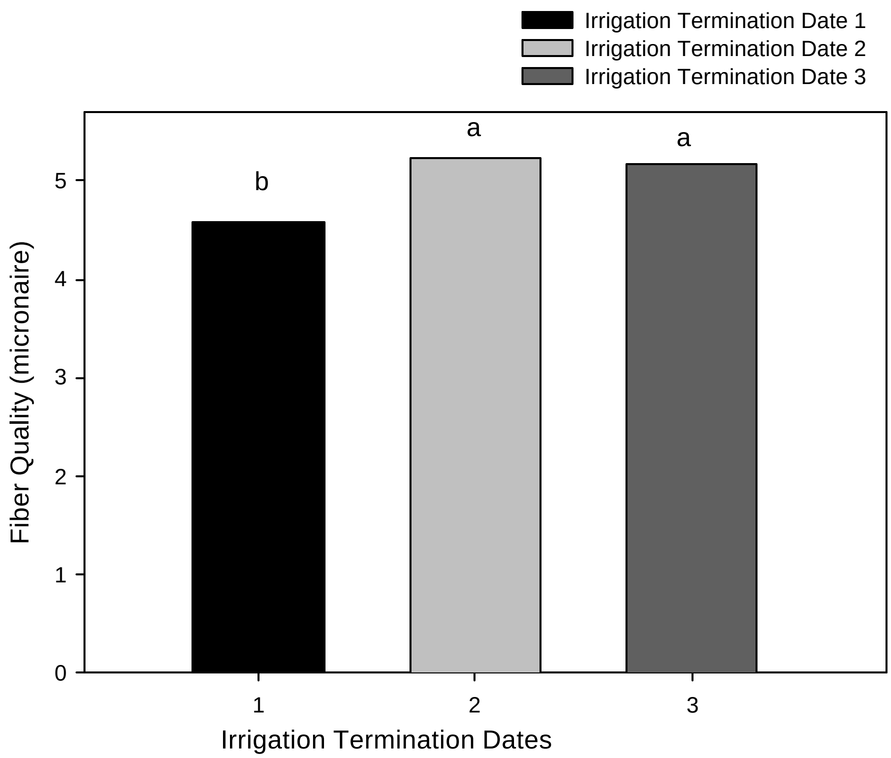

Fig. 3. Mean micronaire values as affected by irrigation termination dates for all varieties, Maricopa, 2000.

Table 6. Yield results for all varieties by irrigation termination dates, Maricopa, AZ, 2000.

Irrigation Termination Date 1 (24 July)	**Lint Yield (lbs. lint/acre)**
ST4691B	1448
SG747	1385
DP451BR	1359
ST474	1334
DP422BR	1283
DP20B	1270
DP388	1245
BXN47	1245
DP428B	1194
DP5415	1131
DP33B	1131
SG125BR	1093
DP655BR	1042
LSD*	204
OSL**	0.0099
CV (%)	9.7
Irrigation Termination Date 2 (15 August)	
ST4691B	1708
DP428B	1619
DP33B	1613
DP20B	1613
SG125BR	1578
DP422BR	1550
DP388	1537
DP451BR	1535

	DP5415	1527
	BXN47	1441
	DP655BR	1385
	ST474	1347
	SG747	1225
LSD*		NS
OSL**		0.0991
CV (%)		11.1
Irrigation Termination Date 3 (15 September)		
	DP33B	1855
	ST4691B	1855
	DP451BR	1842
	DP428B	1829
	SG747	1829
	DP20B	1741
	SG125BR	1728
	ST474	1702
	DP655BR	1690
	DP422BR	1677
	BXN47	1626
	DP5415	1601
	DP388	1544
LSD*		NS
OSL**		0.2218
CV (%)§		8.5

*Least Significant Difference (LSD)
**Observed Significance Level at the 0.05 level.
§Coefficient of Variation

Table 7. Yield results by variety for each irrigation termination date, Maricopa, AZ, 2000.

Irrigation Termination Date	**BXN 47**	**DP 20B**	**DP 33B**	**DP 388**	**DP 422BR**	**DP 428B**	**DP 451BR**	**DP 5415**	**DP 655BR**	**SG 125BR**	**SG 747**	**STV 4691B**	**STV 474**
1	1245	1271	1131 b	1233	1283	1194 b	1359	1131	1042 b	1093 b	1385 b	1448	1334 b
2	1441	1614	1614 a	1525	1550	1617 a	1534	1527	1385 ab	1578 a	1225 b	1708	1347 b
3	1626	1741	1855 a	1531	1677	1829 a	1842	1601	1690 a	1728 a	1829 a	1855	1702 a
LSD*	NS	NS	449	NS	NS	370	NS	NS	450	423	413	NS	274
OSL**	0.2212	0.0664	0.0260	0.115	0.1466	0.0211	0.1149	0.1904	0.0402	0.0302	0.338	0.1243	0.0334
CV (%)§	15.3	11.4	12.9	4.3	12.9	10.6	13.6	19.2	14.5	127	12.3	11.1	8.3

*Least Significant Difference – means followed by the same letter within a column are not significantly different according to a Fishers means separation test at 0.05 level.

**Observed Significance Level.

§Coefficient of Variation.

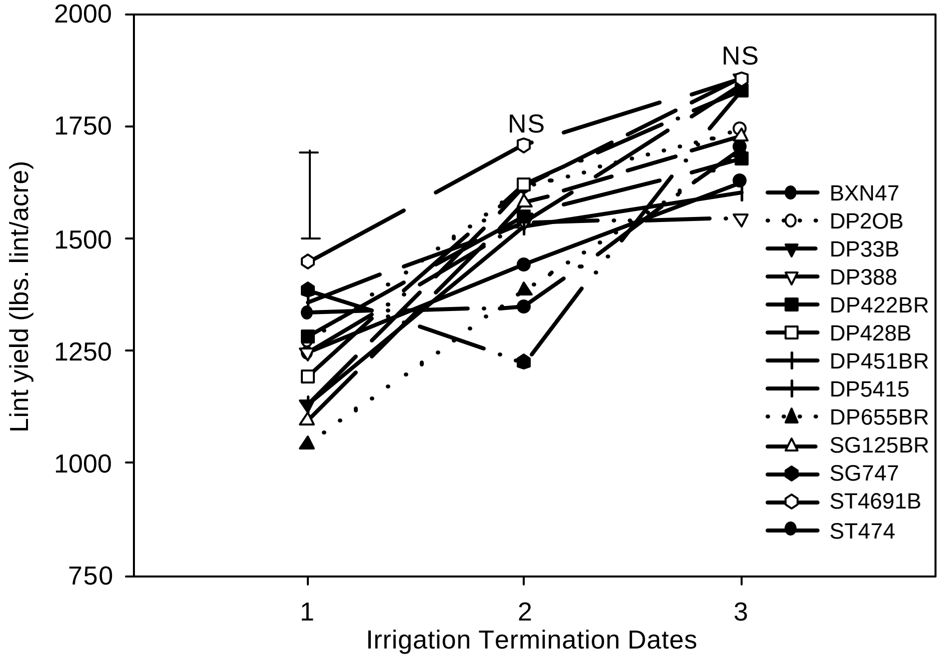

Fig. 4. Lint yield as affected by irrigation Termination Dates for each variety, Maricopa, 2000.

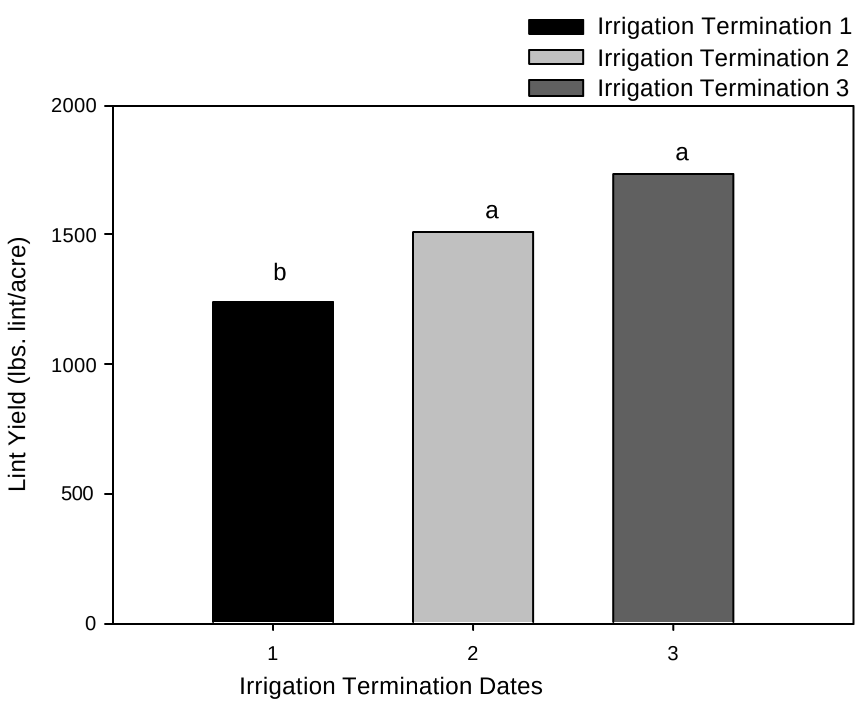

Fig. 5. Mean lint yield as affected by irrigation termination dates for all varieties, Maricopa, 2000.