Evaluation of Date of Planting and Irrigation Termination on the Yield of Upland and Pima Cotton

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Abstract

Five field experiments were conducted at three locations in 1991 in Arizona to evaluate the response of Upland and Pima cotton to dates of planting and dates of irrigation termination. Planting dates ranged from as early as 2 April in the Yuma Valley (150 ft. elevation) to 14 May at Marana (2,000 ft. elevation). Dates of irrigation termination ranged from 8 August in the Yuma Valley to 24 September at Maricopa. Planting date was commonly a significant effect in these experiments, particularlywith Pima cotton. Irrigationtermination results over three locations and three seasons show increases of approximately 50 to 100 lbs. lint/acre by extending later irrigations.

Introduction

There are many factors to consider with regard to pursuing long, full season cotton (Gossypium spp.) production versus the use of an earlier termination of the crop and a shorter season production scenario. Traditionally, at the lower elevations in the state (below 2,000 ft.) the cotton growing season has been extended in excess of 200 or 250 days in an effort to make use of the available season (heat units) and strive for maximum absolute yield potentials. The relative merits of short versus full-season production have been discussed and debated extensively. Entomologists have emphasized points regarding cultural production practices and the relation to biological constraints of certain insect pests in an effort to achieve greater control over these pests. Other positive aspects of pursuing a shorter cotton production system would include the reduction of major inputs such as water, fertilizer, and insecticide costs due to an earlier crop termination, and the preservation of high quality cotton lint (Farr, 1989; Silvertooth and Terry, 1989). These have always been important considerations, but factors such as high water costs in many areas, and the threat of diminished quality due to late season insect infestations, such as whitefly, have created additional incentive for growers to consider a shorter season management approach than may have been traditionally practiced.

With this general background, and drawing from earlier research work with date of planting experiments and irrigation termination experiments, a project was initiated in 1989 (Silvertooth et al., 1990 and Silvertooth et al., 1991) with the objective of developing agronomic guidelines adaptable across a range of conditions in Arizona (basically below 2,000 ft. elevation) for pursuing an optimization of Upland (G. hirsutum L.) and Pima (G. barbadense L.) cotton production. Planting dates (PD) were chosen with one date close to an optimum (based on weather conditions and date of planting research) and a second date slightly past an optimum point. This was due to the fact that highest yields often are obtained with more indeterminate varieties at relatively early planting dates, which also respond to delays of planting past an optimum period with substantial declines in yield potential and increased vegetative tendencies (Silvertooth, et al, 1989).

The dates of irrigation termination (IT) were selected with the initial date of termination being imposed at a time after cut-out in the Upland crop, so that bolls set prior to cut-out could be matured with adequate soil-water available through that period. That estimate requires a projection of time (heat units) needed to mature the fruit while maintaining available soil water over that period. The first date of termination with the Pima crop must be somewhat more subjective or arbitrary due to a more sustained flowering and fruiting phase, with often no distinct cut-out. Thus, this must be adjusted based upon the season and the fruiting pattern of the crop. The second date of termination usually occurs two additional irrigation events past the early termination, allowing the development of a "top crop" or second fruiting cycle as in the case of the Upland crop particularly.

Methods

A group of three field experiments were conducted at the University of Arizona Agricultural Centers at Yuma Valley (YVAC), Maricopa (MAC), and Marana for the purposes of comparing the effects of PD and IT on the growth and development, yield, and quality of Upland and Pima cotton (Table 1). The basic experiments were structured as a split-split plot within a randomized complete block design, with four replications. In this design, PD represent whole units (mainplots), and IT dates as subunits (subplots). The smallest experimental unit (termination treatments, subunits) was eight, 40-inch rows wide, and extended the full length of the irrigation run. Identical experiments were located at YVAC, MAC and Marana. A fourth experiment was also located at MAC which involved two Upland varieties (DPL 51 and 90), and Pima S-6 (whole units), planted at one date, with three dates of IT (subunits), and three full replications in a randomized complete block design. These experiments have been added to the original plan of work to compliment the basic experimental structures with additional information regarding effects of IT (three points). A fifth experiment at MAC involved two row spacings as mainplots (30 and 40 inch), three dates of IT as subplots, and two Upland varieties as sub-subplots (DPL 5415 and DPL 20), with three replications within a randomized complete block design.

Routine plant measurements for all experiments were carried out on a regular basis at approximately 14-day intervals throughout the season. Measurements taken included: plant height, number of mainstem nodes, number of flowers per 25 feet of row, the number of nodes from the top fresh bloom to the terminal (NAWB) and percent canopy closure. Plant mapping data was also collected on a sequential basis through the season for all treatment combinations, at each location. Petiole samples were collected on a regular basis for NO_3-N analysis for the purposes of managing N fertility through the season in an optimal fashion. Heat unit accumulations after planting (HUAP, using 86/55 °F thresholds) were recorded by local AZMET meteorological stations.

Experiments at Yuma, Maricopa, and Marana were harvested by use of mechanical pickers on 8 August, 9 September, and 5 October (Yuma); 31 October, 4 November and 12 November (Maricopa); and 20 November (Marana).

Results

Early season crop initiation and development was substantially delayed at all three locations in 1991 due to extremely cool weather conditions in March. However, after May, generally warm and dry weather patterns prevailed, providing conditions which were favorable for maintaining high fruit retention levels. The fruit retention patterns shown for Yuma Valley (Figure 1), Maricopa (Figures 2, 3, 4, and 5), and Marana (Figure 6) are indicative of the generally favorable fruit load observed at each location. Therefore, despite the delay in early season crop progression in 1991, fruit development and retention were favorable throughout the first cycle fruit set period at each location.

Yuma Valley

A significant yield response was detected for PD effects with Pima S-6 ($P \leq 0.001$), with a similar pattern determined for the DPL 90 also (yet not statistically significant). Differences in PD were 2 April and 23 April, 571 and 889 HU accumulated since 1 January, respectively. Actual lint yield means are shown in Table 2. These results exemplify the sensitive nature of an indeterminate variety such as Pima S-6 to PD and the effect created by a delay in PD on yield potential, for both dates of irrigation termination. From the standpoint of optimum yield potentials, the first PD and early IT treatment produced yields which were very comparable to the early

PD and later IT. It is important to note that the later IT (for the same PD) required two additional irrigations (approximately 12 acre inches of water).

Maricopa

Early season fruit retention levels for the PD*IT experiment at MAC were rather low (less than 80% on 20 June and 17 July), as shown in Figure 2. However, retention levels in August were nearly 60%. Correspondingly, plots for both PD treatments approached cut-out in a reasonable fashion for a full season Upland variety. Even though PD 2 plots experienced somewhat greater vegetative tendencies relative to PD 1 (Figure 3), PD effects were not statistically significant. The IT effects however were significantly different ($P \leq 0.05$). Lint yield means are shown in Table 3, indicating a similar trend found at the Yuma location. However, at this location a substantial increase in yield due to late season compensation is shown for the later IT over the first, particularly with the second PD. This was commonly experienced in central Arizona in 1991 due to favorable weather in September and October for late season fruit development. It is also interesting to note that if one were striving for a relatively early IT, the yield potential would be severely diminished by delaying PD from approximately 400 HU accumulated since 1 January to 800 HU accumulated since 1 January with a variety similar to DPL 90.

The variety x IT experiment utilizing three different types of cotton maturity groups (DPL 51, medium maturity; DPL 90, full-season Upland; and Pima S-6 a more indeterminate crop) was structured with three IT dates in an attempt to define the response of these cotton types to late season development. Having three IT dates allows for a better description of a point of diminishing return. The lint yields shown in Table 4 reveal significant yield increases ($P \leq 0.05$) for the last IT as compared to the first two for the DPL 51 and DPL 90. It is important to recognize that mean yield differences of approximately 105 and 46 lbs. of lint/acre were realized by the last IT for the DPL 51 and DPL 90, respectively over the average of the first two IT dates of each. Therefore, even though yield differences were realized for these two varieties, they were only slight. This is particularly important given that I2 and I3 used approximately six and twelve additional acre inches of irrigation water by IT 2 and IT 3, respectively, relative to IT 1.

Row spacing comparisons between conventional, 40 inch and narrow, 30 inch rows were part of the 1989 and 1990 experiments at Maricopa (Silvertooth et al., 1990 and Silvertooth et al., 1991) using DPL 90 as a test crop with two dates of PD and IT also as variables. Under the 1989 and 1990 experiments no differences in yield due to row spacing were detected with DPL 90. In the 1991 experiment, a medium (DPL 5415) and a short-season (DPL 20) variety were used with a common PD and three dates of IT. It was hypothesized that the most determinant variety (DPL 20) would have the greatest possibility for expressing a positive yield response to a narrow row culture when restricted to a relatively short production season, as would be imposed by an early IT. The IT treatments for the 1991 experiment were structured similar to all others, in that IT 1 was imposed in a manner that provided adequate soil moisture for the development of all fruit set by cut-out. The second and third IT dates provided an additional six and 12 acre inches of irrigation water, respectively. Both the DPL 5415 and the DPL 20 developed excellent fruit loads, under both 30 and 40 inch rows (Figure 5). Actual canopy closure was found to progress slightly faster for the 30 inch rows with DPL 5415 and DPL 20 (Table 5). However, after 15 July (1811 HUAP) differences between 30 and 40 inch rows became negligible for DPL 5415 and DPL 20. Final lint yield means and standard deviations for this experiment are shown in Table 6. No differences due to row spacings were found. The DPL 5415 responded with higher average yields than did the DPL 20, which is understandable considering the relative differences in general maturity groups these varieties represent and planting dates at this elevation. It is also interesting that no differences in yield were obtained due to later IT treatments, indicating favorable yield potentials were developed with a short growing season (2700 HU from planting to final irrigation; 15 April to 15 August).

Marana

Poor fruit retention was experienced early in the season at the Marana experiment in 1991 (Figure 6). However, mid-to late-season patterns indicated some improvement and compensation for early fruit loss. The inability of later PD plots to recover yield potentials was shown by the significant PD effects found for the DPL 90 ($P \leq 0.01$) and the Pima S-6 ($P \leq 0.001$). A significant IT effect was also found with the DPL 90 ($P \leq 0.05$). Lint yield means are listed in Table 7 revealing the extreme sensitivity expressed by both DPL 90 and Pima S-6 to delays in planting from 18 April to 14 May; which represents a delay from 542 to 895 HU accumulated since 1 January.

Summary

The results obtained from nine site-years of data from the PD*IT experiments at YVAC, MAC, and Marana over 1989, 1990, and 1991 have generated some interesting trends (Tables 8 and 9). For the Upland tests (DPL 90), PD has been a statistically significant effect nearly 70% of the time (Table 8) when establishing the first PD near the front and the second PD near the close of the 300 to 900 HU (accumulated since 1 January) window defined as a general optimum for full season varieties (Silvertooth et al., 1989 and Silvertooth et al., 1991). The similar case has been shown true for Pima S-6 with nearly 80% of the site-years in these studies revealing a significant PD effect (Table 9). We often regard IT as having the most profound affect on yield potentials. But these studies clearly indicate the importance of PD and it's impact on establishing a crops growth and development patterns. This information also provides the basis for refinement of the optimum HU window for planting full season varieties. These results clearly indicate that planting full season varieties beyond 700 HU after 1 January leads to diminished yields. A more optimal window for planting full season varieties is from 300-700 HU after 1 January. Growers should attempt to switch to medium and short maturity-type varieties after 700 HU have accumulated since 1 January (Figure 7).

In an effort to improve efficiencies in Arizona cotton production systems, the identification of a timely final irrigation date (IT) is critical. These experiments have attempted to identify IT dates as a function of cut-out occurrence, with the later IT dates being set so as to provide approximately two additional irrigations (and approximately an additional acre foot of water) to sustain some later fruit or top-crop development. Considering the fact that earlier PD's have been generally more favorable in these studies, Table 10 was developed by calculating the differences in mean lint yields obtained by carrying the DPL 90 and Pima S-6 crops into late season development (by extending the second IT date for the earlier PD's). In general, the actual yield differences obtained commonly range from about 70 to 150 lbs. lint/acre. The exceptiona. case is demonstrated by the Yuma Valley DPL 90 in 1990, which produced an additional 592 lbs. lint/acre due to an extra two irrigations. This was a case in which very little fruit-set had been accomplished prior to the first IT due to inclement weather (hot, humid conditions with high night temperatures). Therefore, it appears from this information that a cotton crop with a reasonable boll load has the potential of producing up to perhaps 150 lbs. lint/acre from a top-crop. A producer considering such an option could use these figures for a realistic yield projection. In making this decision one must take into account the actual costs of production to carry the crop over that additional period; including insect pest control needs, irrigation, defoliation needs, and quality effects on the harvestable lint. These factors become essential ingredients for development of a formula to describe the point of diminishing returns for a cotton crop and the pursuit of optimum production efficiency.

References

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Table 1. Locations, planting dates, and heat unit accumulations (HU) in 1991 for the date of planting and irrigation termination experiments.

		Accumulated HU			
Location	Planting Date	At Planting*	15 June**	15 July	1 September
		(86/55 degrees F)			
Yuma Valley	2 April	571	1350	2143	3497
	23 April	889	1032	1825	3179
Maricopa	5 April	391	1165	1923	3212
	10 May	839	718	1475	2764
Marana	18 April	542	968	1708	2956
	14 May	895	615	1355	2603

* HU accumulated since 1 January, 1990.
** HU accumulated since planting.

Table 2. Lint yield means for DPL 90 and Pima S-6 for two dates of planting and two dates of irrigation termination, Yuma Valley, AZ, 1991.

Planting Date§	Irrigation Termination Date (HUAP) †	Yield DPL 90	Yield Pima S-6
		------------lbs. lint/acre-------------	
2 April	8 August (3362)	1609 c	1458 b c
2 April	5 September (4181)	1540 b c	1705 c
23 April	22 August (3770)	1416 a	1114 a
23 April	18 September (4504)	1499 a b	1293 a b

§ 2 April had 571 HU (Heat Units, 86/55 °F thresholds) and 23 April had 889 HU accumulated since 1 January, respectively.

† HUAP, Heat Units accumulated since planting.

* Means followed by the same letter within a column are not significantly different ($P \leq 0.05$) according to single degree of freedom orthogonal contrasts.

Table 3. Lint yield means for DPL 90 for two dates of planting and two dates of irrigation termination, Maricopa, AZ, 1991.

Planting Date §	Irrigation Termination Date (HUAP) †	Yield ----------lbs.lint/acre--------
5 April	15 August (2753)	971 a b*
5 April	18 September (3593)	1064 b
10 May	15 August (2305)	829 a
10 May	18 September (3145)	1117 b

§ 5 April and 10 May had 391 and 839 Heat Units (HU, 86/55 °F thresholds) accumulated since 1 January.

† HUAP, Heat Units accumulated since planting.

* Means followed by the same letter within a column are not significantly different ($P \leq 0.05$) according to single degree of freedom orthogonal contrasts.

Table 4. Lint yield means for DPL 51, DPL 90, and Pima S-6 for three dates of irrigation termination, Maricopa, AZ, 1991.§

Variety	Date of Irrigation Termination (HUAP)§			
	29 August (3523)	11 September (3838)	24 September (4129)	LSD 0.05
DPL 51	1207 b*	1222 b	1320 a	92
DPL 90	1170 b	1154 b	1208 a	31
Pima S-6	1004 a	930 a	1018 a	NS

§ Planted on 9 April, 450 HU since 1 January

† HUAP, Heat units accumulated since planting (86/55 °F thresholds)

* Means followed by the same letter within a row are not significantly different ($P \leq 0.05$) according to pairwise comparisons using a Fisher's LSD.

Table 5. Canopy closure percentages for both 30 and 40 inch row spacings with DPL 5415 and DPL 20, Maricopa, 1990.*

Sample Dates (HUAP) **	Canopy Closure			
	DPL 5415		DPL 20	
	30 in.	40 in.	30 in.	40 in.
	% closure			
18 July (1129)	53	27	53	30
1 July (1427)	64	41	66	43
15 July (1811)	87	62	90	60
29 July (2189)	93	97	96	100
13 August (2583)	100	100	100	100

* Planting date on 10 April (465 HUAP).

** HUAP, Heat units after planting (86/55 °F thresholds).

Table 6. Lint yield means and standard deviations for DPL 5415 and DPL 20 for two row spacings (30 and 40 inch) and three dates of irrigation termination, Maricopa, AZ, 1992.

Irrigation Termination Date (HUAP)*	Row Spacing	
	30 inch	40 inch
	------------lbs.lint/acre--------------	
	DPL 5415	
15 August (2656)	1528 ± 118	1520 ± 33
30 August (3100)	1587 ± 157	1638 ± 123
12 September (3394)	1563 ± 45	1569 ± 175
	DPL 20	
15 August (2656)	1437 ± 146	1383 ± 65
30 August (3100)	1457 ± 195	1367 ± 64
12 September (3394)	1412 ± 242	1415 ± 73

* HUAP, Heat units (86/55 °F thresholds) accumulated after planting (15 April, 503 HU after 1 Jan.)

Table 7. Lint yield means for DPL 90 and Pima S-6 for two dates of planting and two dates of irrigation termination, Marana, AZ, 1991.

Planting Date §	Irrigation Termination Date (HUAP) †	Yield DPL 90	Yield Pima S-6
		---------lbs.lint/acre---------	
18 April	6 September (3075)	1314 b	928 b
18 April	20 September (3368)	1424 c	1129 c
14 May	6 September (2722)	1089 a	550 a
14 May	20 September (3015)	1109 a	647 a

§ 18 April and 14 May had 542 and 895 Heat Units (HU, 86/55 °F thresholds) accumulated since 1 January, respectively.

† HUAP, Heat Units accumulated since planting.

* Means followed by the same letter within a column are significantly different ($P \leq 0.05$) according to single degree of freedom orthogonal contrasts.

Table 8. Analysis of variance results for lint yield from date of planting by irrigation termination experiments in Arizona, DPL 90, 1989, 1990, and 1991.

Effects	Yuma Valley	Maricopa	Marana
		1989	
PD	*§	NS	*
IT	NS	*	NS
PD*IT	NS	NS	NS
		1990	
PD	*	*	*
IT	*	NS	NS
PD*IT	NS	NS	NS
		1991	
PD	NS	NS	**
IT	NS	*	*
PD*IT	NS	*	NS

§ *,**,***indicate significance at P=0.05,0.01,and 0.001,respectively
NS indicates non-significant (P ≤0.05)

Table 9. **Analysis of variance results for lint yield from date of planting by irrigation termination experiments in Arizona, Pima S-6, 1989, 1990, and 1991.**

Effects	Yuma Valley	Maricopa	Marana
		1989	
PD	*§	NS	*
IT	NS	*	NS
PD*IT	NS	NS	NS
		1990	
PD	*	*	*
IT	*	NS	NS
PD*IT	NS	NS	NS
		1991	
PD	***	NS	***
IT	NS	NS	NS
PD*IT	NS	NS	NS

§ *,**,***indicate significance at P=0.05,0.01,and 0.001,respectively
NS indicates non-significant (P ≤0.05)

Table 10. Mean lint yield differences - early term. vs. late term. from early planting dates, 1989, 1990, and 1991.

	1989		1990		1991	
	Upland	Pima	Upland	Pima	Upland	Pima
Yuma Valley	178	152	592	54	0	247
Maricopa	175	184	131	207	94	15
Marana	10	40	10	15	110	202
Average	121	125	244	92	68	155

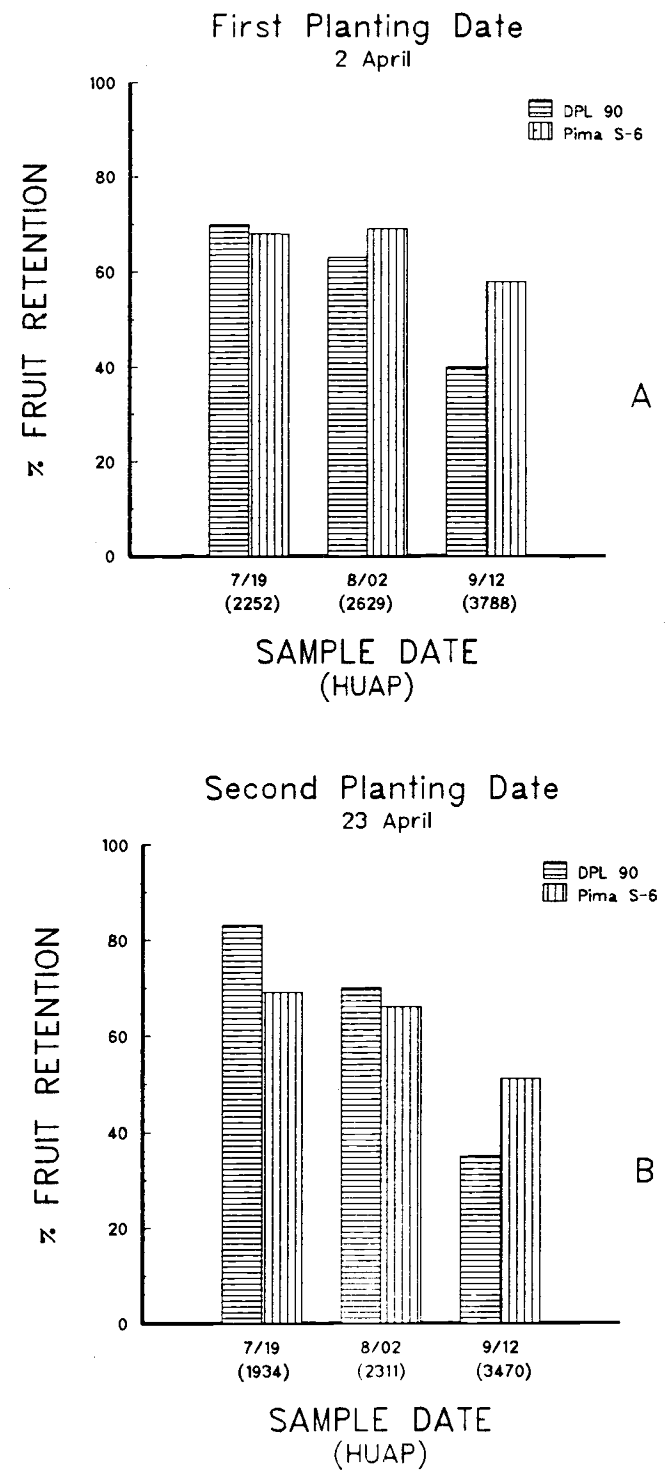


Fig. 1. Percent fruit retention for DPL 90 and Pima S-6 at planting dates A) 2 April, and B) 23 April, Yuma Valley, 1991.

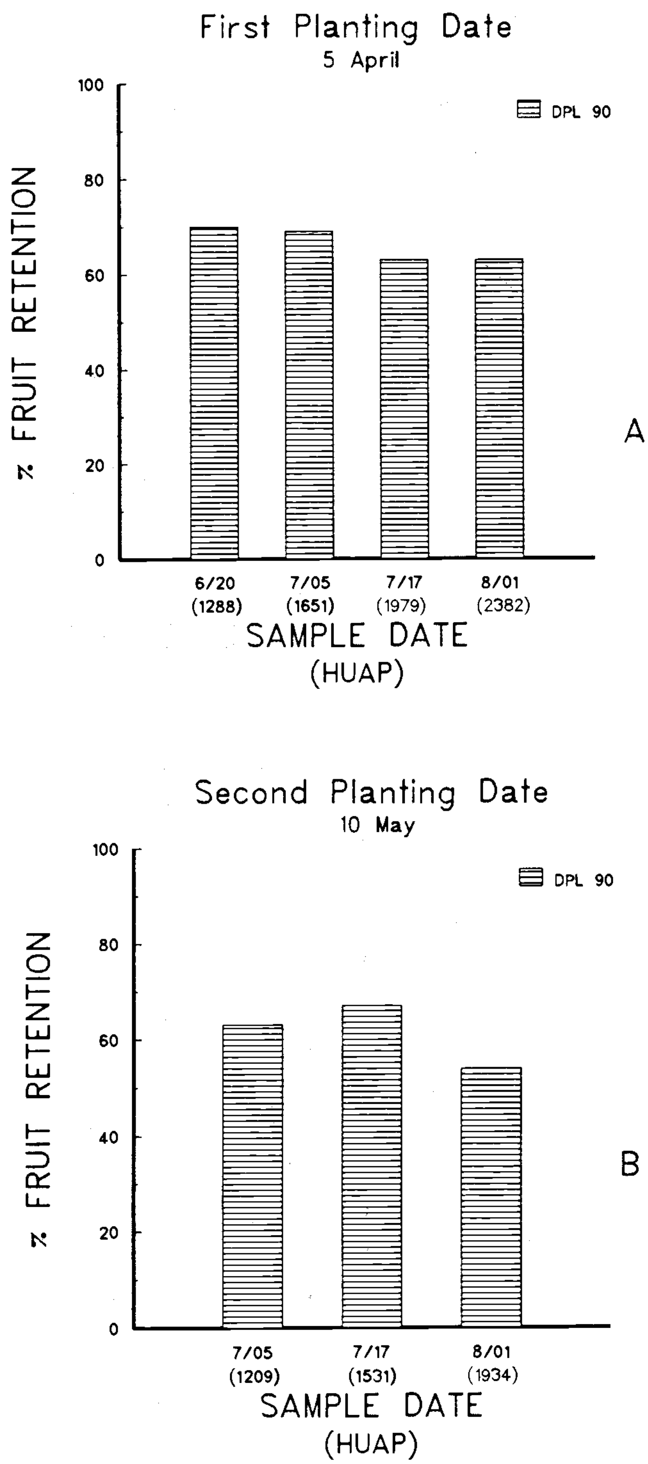
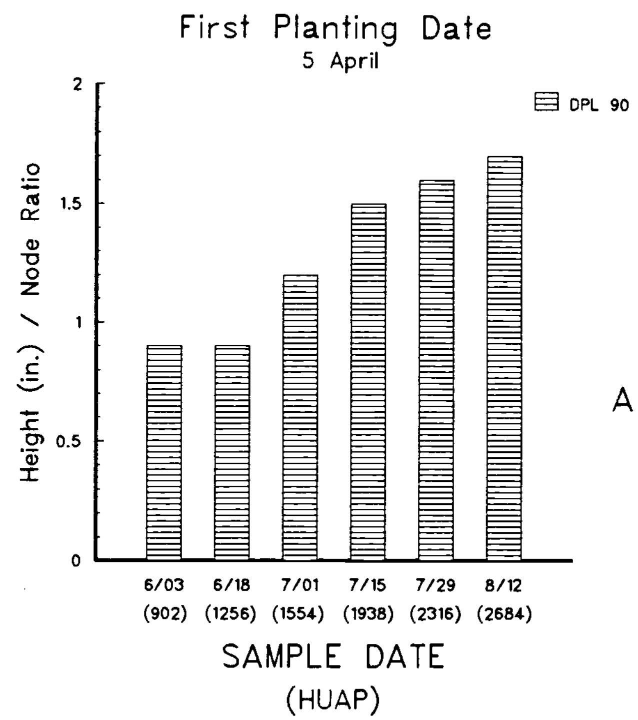


Fig. 2. Percent fruit retention for DPL 90 at planting dates A) 5 April, and B) 10 May, Maricopa, 1991.



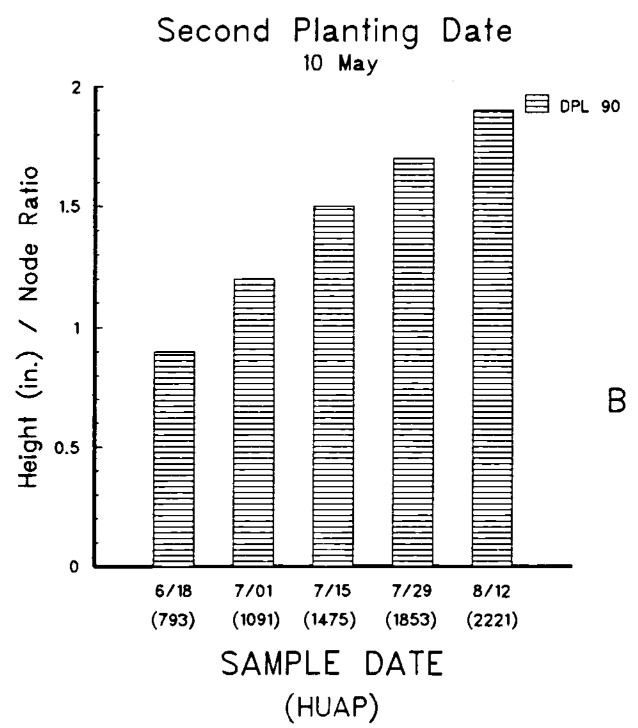


Fig. 3. Height (inches) : Node ratios for DPL 90 at planting dates A) 5 April, and B) 10 May, Maricopa, 1991.

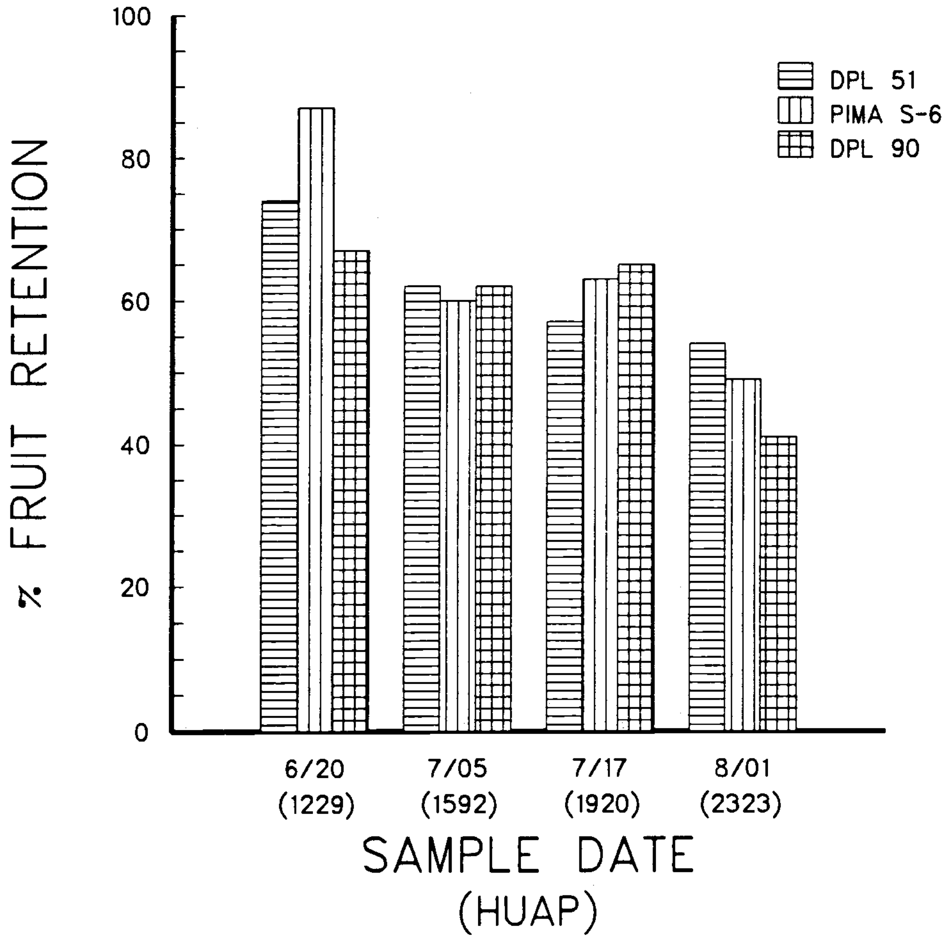


Fig. 4. Percent fruit retention for DPL 51, DPL 90, and Pima S-6, Maricopa, 1991.

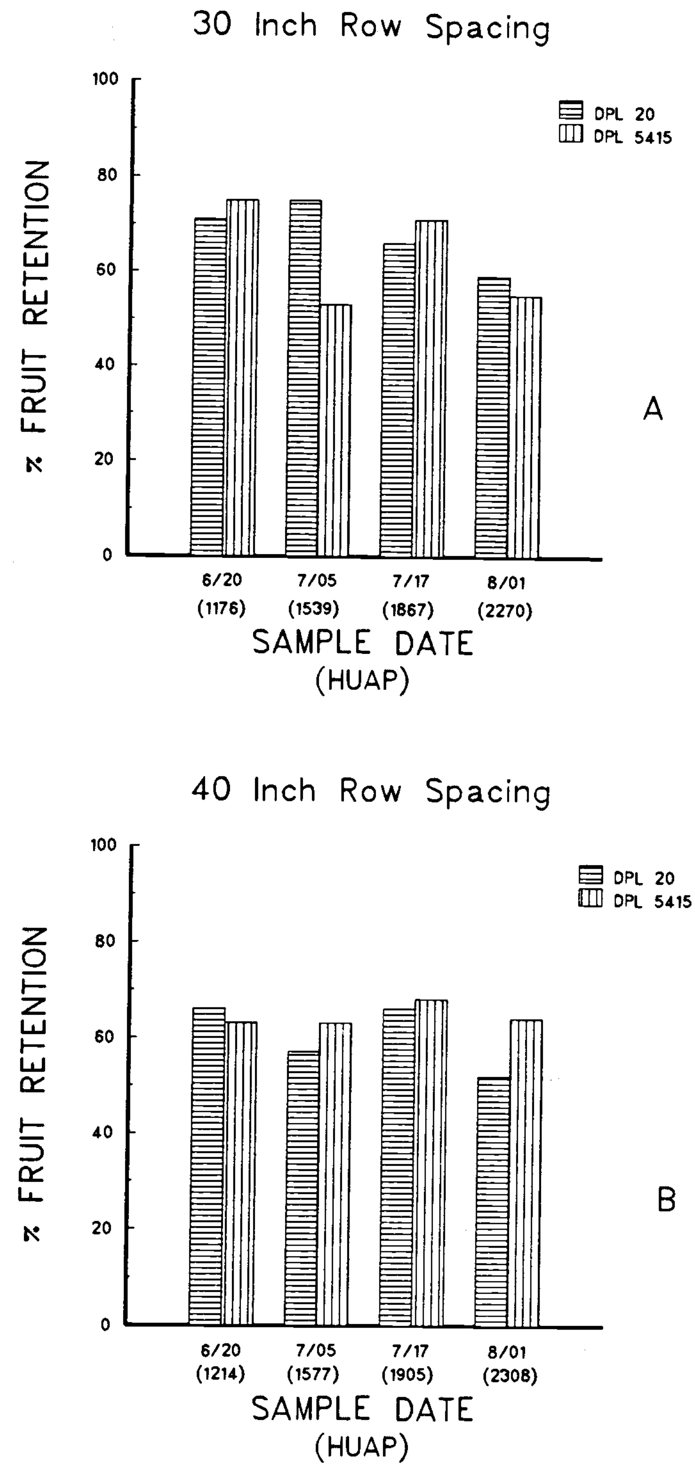


Fig. 5. Percent fruit retention for DPL 5415 and DPL 20 with A) 30 inch rows, and B) 40 inch rows, Maricopa, 1991.

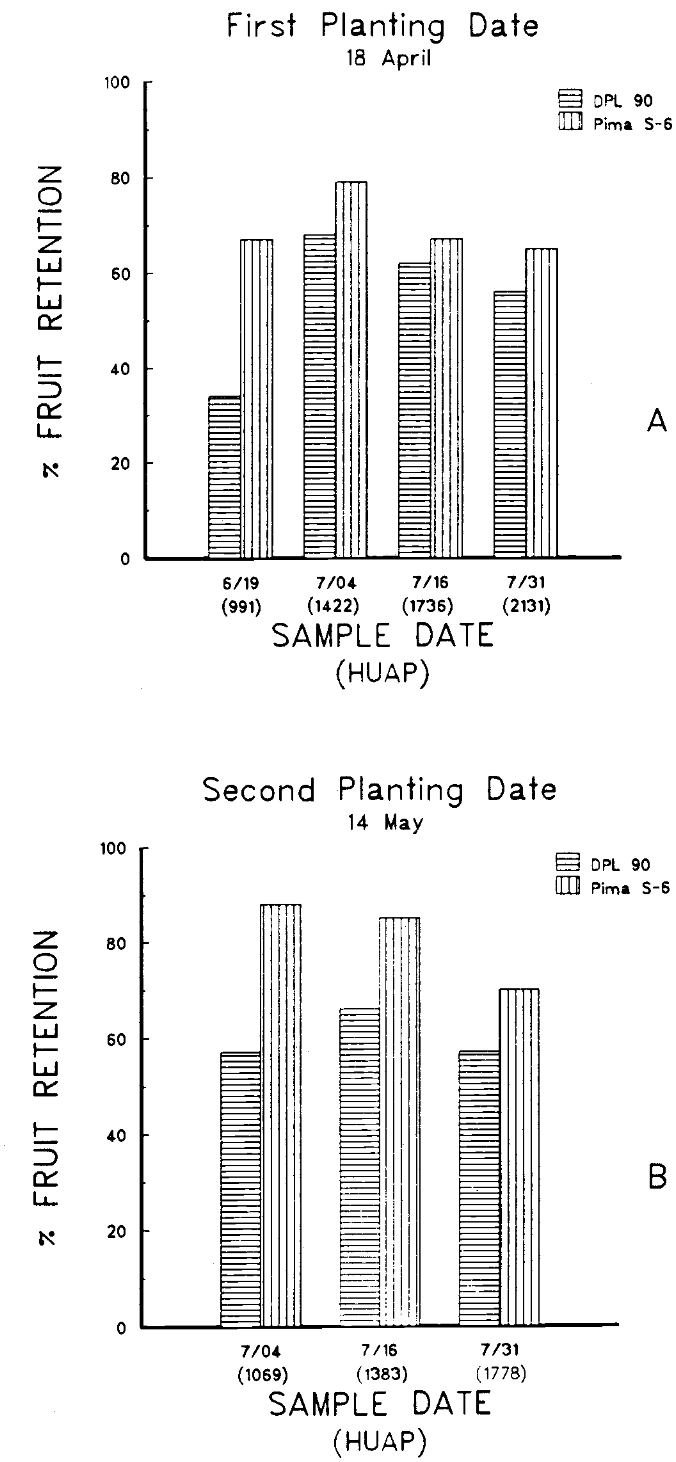


Fig. 6. Percent fruit retention for DPL 90 and Pima S-6 at planting dates A) 18 April, and B) 14 May, Marana, 1991.

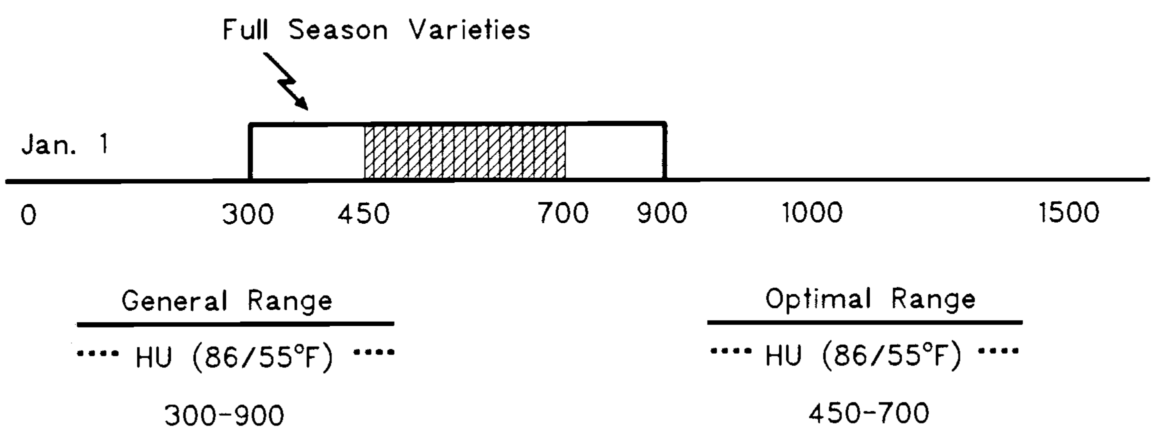


Fig. 7. Optimum planting ranges for full season cotton varieties (Upland and Pima) as a function of heat unit (86/55°F) accumulations since 1 January, for Arizona cotton growing areas.