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Partitioning Yield Reduction from Early Cotton Planting[1]

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ABSTRACT

Delayed cotton (*Gossypium* spp.) planting generally reduces lint yield because it reduces the length of the growing season. Planting cotton too early also can reduce lint yield. Most growers believe that reduced yield with early planting is caused by reduced stand. Previous research suggested that low temperature during germination and early seedling growth may reduce lint yield regardless of stand. This study attempts to clarify low temperature effects on lint yield by partitioning cotton lint yield reduction from early planting into the effects from reduced stand and other factors. Soils were Typic Torrifluvents. Thermic Torrifluvents, and Anthropic Torrifluvents. Upland cotton (*Gossypium hirsutum* L.) had significantly ($P < 0.05$) reduced lint yield from early planting in five tests. American pima cotton (*G. barbadense* L.) grown in four of the tests had smaller, nonsignificant lint yield decreases from early planting in three of the tests and higher lint yield from early planting in the fourth test. Early planted cotton generally was shorter. A comparison of upland cotton lint yields, using adjustment by regression analyses with plant population, indicated that something other than plant population, presumably low temperature, caused approximately 100, 94, 66, 22, and 0 % of the lint reduction from early planting in five analyses. Thus physiological and morphological effects of low temperatures early in the cotton planting season often may contribute as much to reduced lint yield as does reduced stand.

***Additional index words:* *Gossypium hirsutum* L., *G. barbadense* L., Plant population, Planting date, Plant height, Low temperature effects.**

RESEARCH has shown that upland cotton (*Gossypium hirsutum* L.) and American pima cotton (*G. barbadense* L.), in a given year, have an optimal planting date that will produce the highest lint yield for a particular field (11). The best planting date varies each year and often is earlier for pima cotton than for upland cotton (11). Planting later than the optimum date in Arizona resulted in a fairly consistent daily decrease in lint yield as planting was delayed (11). This was explained by a reduced growing season.

The effect of earlier-than-optimum planting on lint yield, in contrast, was erratic (11). Planting too early is a common problem in cotton production, primarily because the best time to plant cotton varies widely from year to year, depending upon weather, for any geographic location. The importance of obtaining a stand was the subject of a series of papers at the 1985 Beltwide Cotton Production Research Conferences (9,14,15,18). They implied that poor stand was the primary factor limiting lint yield when cotton was planted too early. However, Christiansen (2,3) and Christiansen and Thomas (4) reported that chilling cotton seed during germination and emergence resulted in reduced final plant height, delayed fruiting, reduced fiber quality, reduced plant dry weight, reduced root development, reduced hypocotyl elongation, reduced leaf size, and in general caused stunting. The degree of stunting was directly correlated with the number of days of chilling (2). They also reported a nonsignificant reduction in lint yield from transplanted cotton that had been subjected to cold stress in the laboratory (4).

Similarly, cotton plants that emerged slowly within a planting had reduced seedling survival and reduced lint yield per plant (19). Glat and Taylor (8) reported that slowly emerging plants had delayed and reduced flower production and 15 to 20% lower lint yield per plant than early emerging plants. Plant physiology reports and reviews usually acknowledge the deleterious effects of low temperature on cotton seed and seedlings (1,5,13), but the concept has been overlooked in some reports (9,14,15,18).

If low temperature stress contributes significantly to lower lint yield from planting too early, even when adequate stands are obtained, it should be included in the decision making process by field agriculturalists. The objective of this study was to partition lint yield reduction from early planting in five date-of-planting tests, using regression analyses with plant population, into yield reduction explained by reduced plant population and the unexplained residual.

MATERIALS AND METHODS

Data from five cotton date-of-planting tests were evaluated to determine if lower plant population explained lint yield reduction from early planting. These tests were selected from 39 cotton date-of-planting tests in the major cotton producing counties of Arizona from 1961 to 1985. The five selected tests were the only ones out of 39 having both elements essential for this analysis, i.e., reduced lint yield from early planting and plant population data.

1977 Test

This test was planted at the University of Arizona Cotton Research Center, Phoenix. It was arranged in a split-split plot design with planting dates of 21 March, 4 April, and 18 April as main plots. Four cultivars, 'Deltapine 61', 'Hopicala', 'Pima S-5', and 'Pima P-32' were subplots. Sub-subplots were plant populations that were unthinned, thinned to 15 cm within the row, and thinned to 30 cm within the row. There were four blocks. Sub-subplots were four rows spaced 1.02 m apart and 12.2 m long, with the center two rows machine-harvested for yield. Stand counts and plant height measurements (four representative plants per plot) were made after harvest on the center rows. The soil was Avondale loam, a fine-loamy, mixed (calcareous), hyperthermic Typic Torrifluvents.

1982, 1983, and 1984 Tests

Date and rate-of-planting tests with upland and pima cotton were conducted at the University of Arizona Safford Agricultural Center during 1982, 1983, and 1984. The tests were split-split plots with five blocks. Main plots were planting dates of near 7 April, 21 April, and 10 May. Subplots consisted of one upland and one pima cotton cultivar. The upland cotton cultivar was 'Deltapine 41' in all years. Pima

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S-5 was planted in 1982 and 1983, while 'Pima S-6' was planted in 1984. Sub-subplots were planting rates of 134 000, 269 000, and 403 000 seed ha^{-1} in 1983 and 1984. In 1982, seed was measured by weight, and was approximately 130 000, 260 000, and 390 000 seed ha^{-1} for upland cotton, and approximately 94 000, 188 000, and 282 000 seed ha^{-1} for pima cotton. Plots were four rows wide (1.02-m row spacing) and 11 m long. All data were taken from the two center rows of each plot. A one-row spindle picker was used to harvest the plots. Gin turnouts of upland and pima cotton were obtained from the local cotton gin on entire trailer loads of each species. Stand counts were made each year on the two center rows of each plot after harvest. Plant height was measured at harvest in 1982 on four representative plants per plot and on eight randomly selected plants per plot in 1984. The soil was Grabe clay loam, a coarse-loamy, mixed (calcareous), Typic Torrifluvents.

Lint yield in 1983 was reduced by storm damage in the last week of September. The loss was estimated to be 10% for upland cotton and 30% for pima cotton.

1985 Test

This test was conducted at the University of Arizona Marana Agriculture Center. It was a split plot with five planting dates (2 April, 23 April, 7 May, 20 May, and 7 June) as main plots and six blocks. Subplots were 12 upland cotton (no pima) cultivars planted in four rows spaced 1.02 m apart and 11 m long. Yields were obtained from the center two rows of each plot by a spindle picker on 20 November. Stand counts and height measurements were obtained after harvest on three of the six replications. Stand counts were made on a single yield row per plot. Four randomly selected plants per plot were measured for plant height. The soil was Pima clay loam, which is a fine-silty, mixed (calcareous), thermic Typic Torrifluvents.

Temperatures at the three test locations decrease as altitude increases. Altitudes are 340, 610, and 880 m for Phoenix, Marana, and Safford, respectively. Average growing season is 310 days for Phoenix and 199 days for Safford. The mean July maximum temperature is 39.1°C for Phoenix and 36.4°C for Safford (J. Redlinger, 1986, personal communication). Reliable climatological data were not available for Marana, but it is known to be intermediate in temperature between Phoenix and Safford. Minimum temperatures for Phoenix are from an unofficial weather station at the Cotton Research Center. Safford temperatures are from an official weather station at the Safford Agricultural Center.

Tests were evaluated by analysis of variance for lint yield. Partitioning of reduced lint yield and confidence intervals ($P < 0.05$) from early planting were accomplished by calculating regression of lint yield vs. plant population (7). The resultant regression lines represent the mean lint yield for the specific planting date at any given plant population. The relationship between plant population and lint yield of pima cotton is quadratic, except for very low plant populations (10). Unpublished data by the authors indicates the same relationship is true for upland cotton. Therefore, quadratic regressions of lint yield vs. plant population were calculated for all comparisons as the best estimate of mean lint yield at any given plant population, even though the linear and quadratic components usually were not statistically significant ($P < 0.05$) in these tests. Means of the 2 upland cultivars in the 1977 test and the 12 cultivars in the 1985 test were obtained for each planting date by use of regression analysis with dummy variables prior to the final regression analysis (17).

RESULTS AND DISCUSSION

The two upland cultivars Deltapine 61 and Hopicala had significantly lower lint yield from the earliest planting in the 1977 test than from the second planting (Table 1). Pima cotton cultivars, in contrast, had significantly higher lint yield from the earliest planting than from the second planting. Reduced lint yield from early planted upland cotton and increased lint yield from early planted pima cotton are consistent with observations of an earlier optimum planting date and an apparent greater tolerance to low temperature by pima cotton (11). Lint yields of the third plantings were lower than the highest lint yield for all cultivars. Lint yield reduction of both upland and pima cotton after the optimum planting date was apparently due to reduced growing season (11).

Highest lint yield was from the second planting in the 1982, 1983, and 1984 tests, except in the 1984 planting of upland cotton, where the third planting produced the highest lint yield (Table 2). Lint yields of earliest planted upland cotton plus the second planting in 1984 were significantly lower ($P < 0.05$) than yield from the planting date with the highest lint yield for the three tests, with an average lint yield reduction

Table 1. Lint yield and difference in lint yield among dates for two upland and two pima cotton cultivars planted on three dates at Phoenix, AZ in 1977.

Cultivar	Planting date			Lint yield difference	
	21 March	4 April	18 April	21 March–4 April	4 April–18 April
	kg ha^{-1}				
Deltapine 61	1220	1515	1292	295	−223
Hopicala	921	1285	940	364	−345
Pima S-5	1268	1024	835	−244	−189
Pima P-32	1171	970	923	−201	−47
$LSD_{0.05}$ = 134					

Table 2. Lint yield and deviation from the highest lint yield (underlined) for upland and pima cotton planted at three dates for 3 yr at Safford, AZ.

Planting date	Lint yield		Deviation from highest yield	
	Upland	Pima	Upland	Pima
	kg ha^{-1}			
		1982		
5 April	1336	797	155	15
21 April	<u>1491</u>	<u>812</u>	0	0
10 May	1138	602	−353	−210
$LSD_{0.05}$ = 135				
		1983		
12 April	645	411	274	65
21 April	<u>919</u>	<u>476</u>	0	0
10 May	790	385	−129	−91
$LSD_{0.05}$ = 67				
		1984		
4 April	1086	926	159	37
23 April	1078	<u>963</u>	167	0
9 May	<u>1245</u>	911	0	−52
$LSD_{0.05}$ = 98				
		3-yr mean		
4–12 April	1022	711	141	39
21–23 April	<u>1163</u>	<u>750</u>	0	0
9–10 April	1058	633	−105	−117

of 189 kg ha^{-1}. First planted pima cotton had lower lint yield than second planted, but the difference (average 39 kg ha^{-1}) was not significant for any of the 3 yr (Table 2). The latest planting produced a significantly lower lint yield ($P = 0.05$) than the second planting date for 1982 and 1983 for both upland and pima cotton.

Early planting (2 April) significantly decreased average lint yield of the 12 cultivars in the 1985 test by an average of 456 kg ha^{-1} as compared to planting on 23 April. Plantings after 23 April resulted in progressive lint yield decreases as the growing season was shortened.

Christiansen and Thomas (4) reported that chilling germinating cotton seeds reduced subsequent plant height. Average plant height decreased from earlier planting (cooler temperatures) in these tests, but the decrease was not consistent.

Quadratic regressions were used to estimate the mean upland cotton lint yields of each of the planting dates at any given plant population (11). Data points for the early plantings, lint yield means as represented by regression lines, and confidence intervals ($P < 0.05$) (7), are shown in Fig. 1 through 4. Data for the 1983 test are not shown since only two data points for the earliest planting had higher plant population than the lowest plant population for the second planting, and the comparison was not considered valid. However, low plant population appeared to be the major cause of reduced lint yield from early planting in the 1983 test. Similar analyses were not obtained on pima cotton because of nonsignificant differences in lint yield.

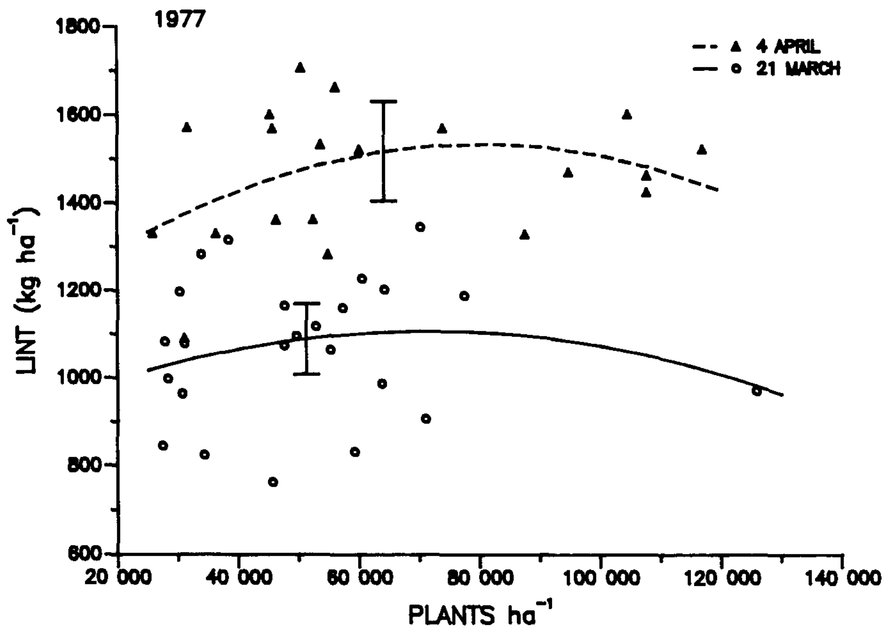

Fig. 1. Mean lint yields (regression lines) and data points for the mean of two upland cotton cultivars from first and second planting dates at Phoenix, AZ in 1977.

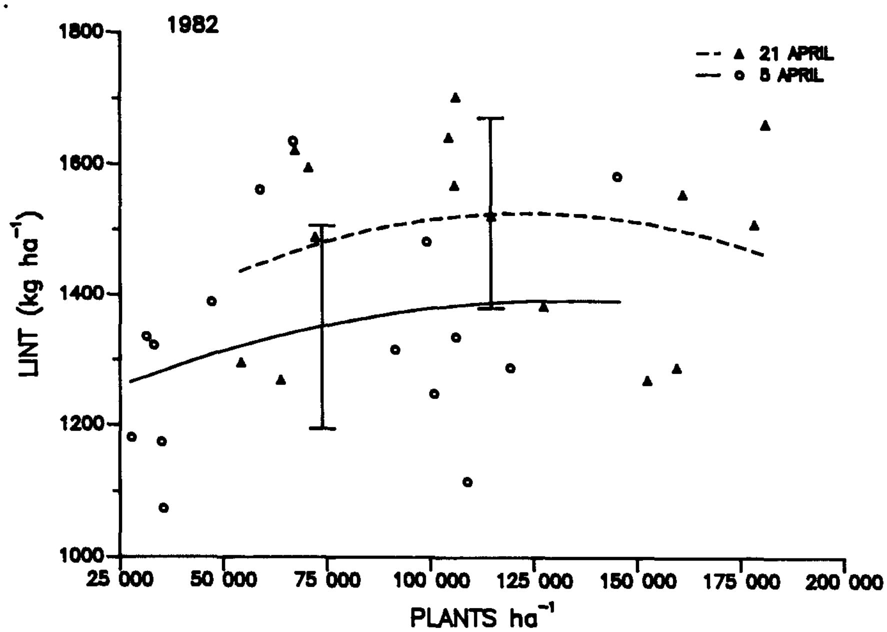

Fig. 2. Mean lint yields (regression lines) and data points for Deltapine 41 upland cotton from first and second planting dates at Safford, AZ in 1982.

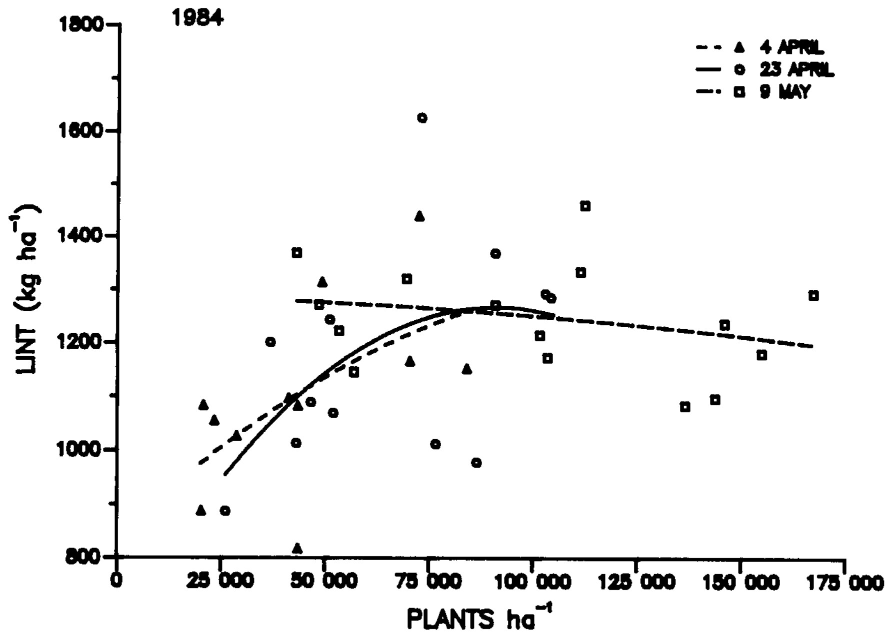

Fig. 3. Mean lint yields (regression lines) and data points for Deltapine 41 upland cotton for three planting dates at Safford, AZ in 1984.

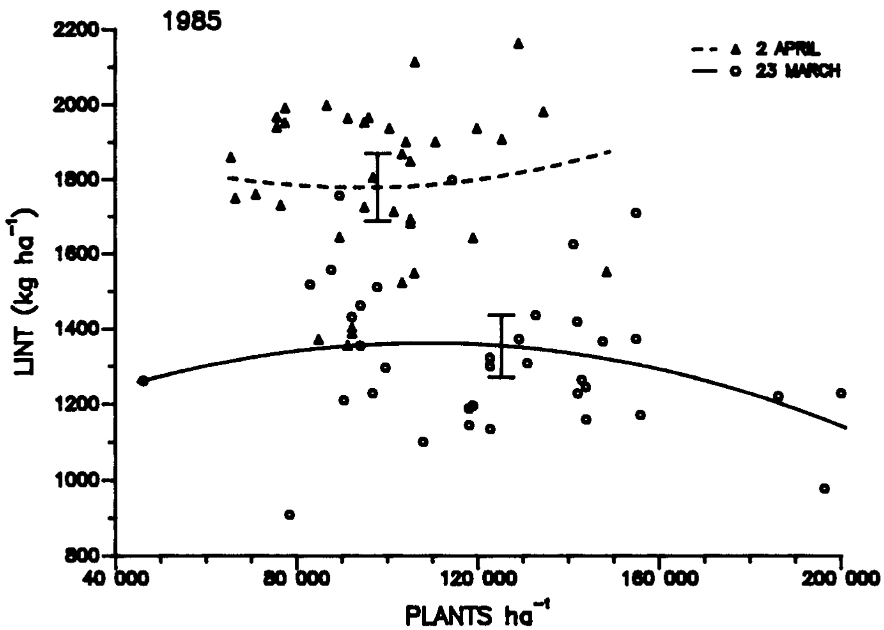

Fig. 4. Mean lint yields (regression lines) and data points for the mean of 12 upland cotton cultivars (adjusted to common means by use of dummy variables) from first and second planting dates at Marana, AZ in 1985.

Figures 1 through 4 show that in some comparisons lint yield reduction from early planting remained as great after considering plant population as in the original means. In other comparisons, plant population was either partially or totally related to the early planting yield reduction. A numerical estimate of the portion of the lint yield reduction attributed to plant population and to nonpopulation factors from early planting was obtained by calculating the difference between regression lines at the mean plant population for the two planting dates and dividing by the original lint yield difference between the two dates. The results, expressed as percentages, are presented in Table 3. The 111% for nonpopulation factors for 1977 can be explained by plant population being closer to optimum for the first planting than the second planting. Thus, if plant population of the second planting had been optimum, the difference in lint yield would have been greater. The data of Table 3 represent the difference at a specific plant population and will vary as plant population varies. Despite this approximation, it is apparent that causes of lint yield reduction from early planting of upland cotton in these tests ranged from entirely due to reduced stand to entirely due to other causes. Low temperature had minimal effect on pima cotton lint yield.

Early season minimum air temperatures for four of the five tests were at or below 10°C most days between the first and second plantings (Fig. 5). The base temperature for laboratory (2) and field (4) studies has been 10°C, but the effect of temperatures lower than 10°C has not been reported. Arbitrary cold units, calculated from planting to 31 May in a manner similar to heat units and using a 10°C base and minimum

Table 3. Partitions of upland cotton lint yield reduction from early planting into reduced stand, other factors, and cold units in five tests in Arizona.

	Percent of lint yield reduction		Cold units Plantings		
Test	Reduced stand	Other factors	1st	2nd	3rd
1977	−11	111	46	8	1
1982	34	66	107	48	21
1983	No comparison	No comparison	171	92	32
1984					
(1st planting)	78	22	141	61	3
(2nd planting)	102	−2		61	3
1985	6	94	--	--	--

† Cold units = Σ (10 °C minus daily minimum temperature) from planting to 31 May.

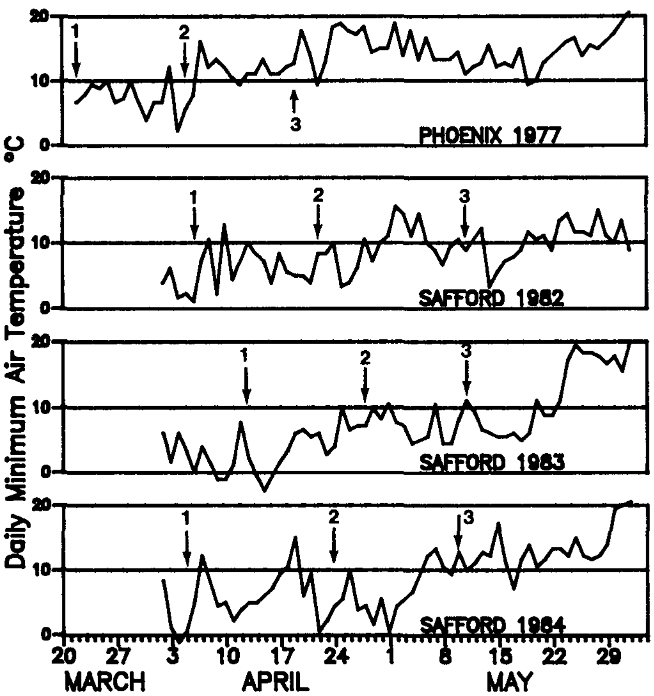

Fig. 5. Early season minimum air temperatures at weather stations near four cotton tests, each with three planting dates.

temperatures, gave some indication of yield response (Table 3). Highest lint yield came with less than 10 cold units in 1977 and 1984. In 1982 and 1983, with gradual reduction in cold units, the highest lint yield came from the second planting. Cold units for the 1985 test were probably similar to the 1977 test based on temperature data away from the test site.

The nature of the physiological and morphological effects of seed and seedling chilling on cotton yield is not clearly understood. These data suggest that lint yield from early planted cotton is positively influenced by a longer growing season and negatively influenced by low temperatures. Therefore, lint yield of early planted cotton, assuming an adequate stand, can be greater or less than lint yield from a later planting, depending upon the relative contributions of the negative impact of cold stress and the positive impact of a longer growing season. It is recognized that indirect factors such as seedling diseases, early season insects, and soil salinity in interaction with low temperatures may also have been factors in reduced lint yield from early planting.

Growers, farm advisors, and agricultural scientists need to be aware that both reduced stands and physiological and morphological changes in plants can reduce lint yields when cotton is exposed to low temperatures during germination, emergence, and early seedling growth. In three of the five tests reported here, replanting of the first planting of upland cotton, even when an adequate stand was obtained, would have been commercially economical. A soil temperature of 15.6°C (60°F) is generally considered the minimum temperature necessary for planting cotton (6,12,16). In practical application, growers that plant cotton early consider soil temperature, but give more consideration to the weather forecast. Further testing in the field and laboratory is needed to identify and quantify temperature variables and plant morphological changes associated with reduced yield from early planting.

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