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Effect of Blooming Date on Boll Retention and Fiber Properties in Cotton[1]

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ABSTRACT

Six cultivars of upland cotton (*Gossypium hirsutum* L.) were studied to determine the influence of blooming date on boll retention and selected fiber properties in experiments conducted over 3 years at a single location. Flowers were tagged at weekly intervals; and after frost, bolls within plots were harvested by tagging dates. Records were kept by dates of blooms tagged/row, tagged bolls set/row, and percent tagged bolls set/row. Fiber properties (2.5% span length, 50% span length, uniformity index, micronaire, and 1/8-inch gauge stelometer) were also studied to determine their patterns of variation.

In general, blooms tagged increased from the beginning of the flowering season until shortly after mid-season, then declined to form a fairly symmetrical distribution. Boll set increased rapidly during the first 3 weeks of the season, then gradually decreased. Percentage boll set was highest at the first of each season, then declined fairly continuously. As a consequence, shedding rate increased in a linear fashion as the seasons progressed. In one instance, it appeared that the cotton plant exhibited increased boll retention efficiency when blooms were limited. The 2.5 and 50% span length measurements exhibited similar distributions within each of the 3 years; however, both showed moderately different patterns between years. Their means did decrease fairly steadily, particularly during the latter part of each season. Evidence in 1 year suggested that about a week's delay was required to obtain a response in the longer fibers comparable to that in the shorter ones. Uniformity index was higher at the end of each season than in mid-season; and in 2 of 3 years, it was also higher at the first of the season. All cultivars except one displayed lower micronaires at the end of the flowering season than at the beginning. The 1/8-inch gauge stelometer reading also declined toward the end of the flowering period.

Relative performance among cultivars for each trait and their differential response patterns over the season are discussed in the text.

***Additional index words:* *Gossypium hirsutum* L., Shedding, Fiber length, Uniformity index, Fiber coarseness, Fiber strength.**

EXPERIMENTS to determine relative performance among cultivars are routinely conducted in all major crops, including cotton (*Gossypium hirsutum* L.). Bridge, Meredith, and Chism (5) have stated that evaluation of cultivars in cotton is a continuous process because new cultivars are periodically released, cultural practices are modified, and new plant types are needed to compensate for changing circumstances. They also note that most successful cultivars have an average use of about 10 years.

In the past, lint yield was *the* major criterion in the breeding and evaluation of new cotton cultivars. Fiber properties were given little attention; but gradually, the importance of characters in addition to yield have also been recognized. Increased competition from synthetic fibers had no small part in bringing about that recognition. In recent years, cotton breeders have made considerable efforts to develop high-yielding cultivars with higher fiber quality; and a number of such cultivars have been released.

Considerable variations in boll characteristics and fiber properties are present within any cotton cultivar. One of the primary factors responsible for that variation is the long flowering and fruiting period of the plant which, in most parts of the Cotton Belt, extends from 6 to 10 weeks (9). This provides the environment with a prolonged opportunity to influence characteristics of the boll and fiber.

The present study was conducted to determine the effect of blooming date on boll retention and on selected fiber properties in cotton. Since differences among cultivars were expected, six were utilized in these experiments. Four of the six were released by the Oklahoma Agricultural Experiment Station; the other two were developed by commercial firms.

LITERATURE REVIEW

Buie (6) in South Carolina published data illustrating that flower numbers increased slowly at first, then rose sharply to a maximum level some 5 to 6 weeks after fruiting had begun, and subsequently declined rapidly over the next 3 weeks. Previously, Ewing (8) had examined flowering trends in Mississippi and showed that the number of flowers increased slowly at first, then more rapidly to a peak, leveled off, and ultimately declined. Hancock (9) in Tennessee also divided the flowering period into three segments: an ascending period, the first 3 weeks; a peak period, the next 2 weeks or 10 days; and a descending period, the remainder of the season.

Munro (14) suggested fruit shedding as one of the primary characters influencing earliness of maturity. He felt environmental factors were more important in shedding than cultivar differences; but when conditions favored shedding, differences among cultivars could be distinguished. Tharp (16) stated that most shedding occurs before blooms open and factors such as drought, extremes in temperature, cloudy weather, and insect and disease damage can cause the phenomenon. He noted a delayed response of 1-1/2 to 10 days after injury before shedding actually takes place (with most occurring after about 7 days). Ehlig and LeMert (7) indicated fruit load as the primary reason in California for low flowering rates and boll retention during mid-season. According to Buie (6), as many as 50% of the immature bolls on the cotton plant may shed under normal conditions; and although fruiting is not rapid in the first 3 weeks, the probability of a square producing a boll is much greater during this period.

Meredith, Bridge, and Chism (13) using four cultivars concluded that, on the average, the third harvest date (out of 10) yielded the longest fiber and length decreased steadily throughout the remaining harvests. Hancock (9) observed that 'Stoneville 2' and 'Trice 90-1' produced their longest fibers during the peak flowering period. Bilbro (4) noted that fiber length gradually decreased from Sep 13 to Nov 12 harvests; and after Nov 12, it increased slightly. However, fibers from his last harvest were the shortest of the season. Meredith and Bridge (12) found fibers were longer and more uniform before "cut-out" then after.

Hancock (9) obtained maximum fiber fineness from bolls produced in the latter part of the flowering period. Bilbro (4) showed that micronaire increased fairly consistently until his early November harvest and decreased rapidly thereafter. Meredith and Bridge (12) and Meredith et al. (13) determined that micronaire differences were greatest among cultivars during earlier harvests and that those differences became progressively smaller for later harvests.

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Table 1. Analyses of variance for boll retention characters and fiber properties.

Source	df†	Mean squares‡							
		NBT	NBS	PBS	2.5% SL	50% SL	UNIF	MIC	T_1
Years (Y)	2 (2)	6883**	1787**	10682.96**	0.023885	0.027161*	89.02**	0.2882	0.6707*
Reps (R) in Y	3 (3)	164	30	340.09	0.004320	0.001206	0.74	0.1369	0.0328
Cultivars (C)	5 (5)	8403**	1294**	3005.83**	0.046276**	0.007770**	92.84**	2.8337**	0.2338**
Y × C	10 (10)	1122*	111	440.53	0.002052*	0.000874*	2.00	0.2374**	0.0281
R × C in Y	15 (15)	352	104	278.62	0.000721	0.000252	1.37	0.0555	0.0195
Dates (D)	5 (4)	33600	12113	94996.74**	0.066448*	0.011762*	7.49	0.6871	0.1500
Y × D	10 (8)	13154**	3768**	6635.02**	0.018368**	0.002859**	27.24**	2.1308**	0.0490**
R × D in Y	15 (12)	320	49	464.65	0.000674	0.000291	1.38	0.0407	0.0047
C × D	25 (20)	1059	464*	457.20	0.000649**	0.000201*	0.95	0.1690	0.0109
Y × C × D	50 (40)	576**	135**	251.17*	0.000275	0.000138	0.91*	0.1077**	0.0058**
R × C × D in Y	75 (60)	199	68**	142.31	0.000225	0.000095	0.48	0.0496	0.0026
Samples in plots	648 --	182	39	128.46	--	--	--	--	--

*, ** Significant at the 0.05 and 0.01 levels of probability, respectively. † Degrees of freedom for fiber property analyses are shown in parentheses. ‡ NBT, no. of blooms tagged; NBS, no. of bolls set; PBS, percentage of bolls set; SL, span length; UNIF, uniformity index; MIC, micronaire; T_1, stelometer.

Hancock (9) demonstrated in two cultivars that fiber strength was highest for bolls developed in the first flowering period. Meredith and Bridge (12) found weaker fiber and yarn from later harvests compared to earlier ones. Meredith et al. (13) showed the third harvest (out of 10) yielded the strongest fiber. Strength decreased sharply in the two harvests following that maximum point. Bilbro (4) established that fiber from his first harvest was significantly stronger than from later harvests. However, no patterns or trends were detected for strength in his later-harvested material.

MATERIALS AND METHODS

These experiments were conducted on the Agronomy Research Station, Perkins, Okla., on a Teller loam soil in 1968, 1969, and 1970. The six cultivars of upland cotton included in these studies were 'Lockett 4789-A' (3), 'Stoneville 7A' (11), 'Kemp' (1), 'Verden' (2), 'Lankburn' (10), and 'Westburn' (10, 15). The first cultivar was developed and released by Lockett Seed Company, Vernon, Tex.; the second by Stoneville Pedigreed Seed Company, Stoneville, Miss.; the last four by the Oklahoma Agricultural Experiment Station, Stillwater, Okla.

These experiments were planted on May 31, 26, and 26 in 1968 through 1970, respectively, in a randomized, complete-block design with six entries (cultivars) and two replications/year. Plots were four rows wide and 11 m long with rows spaced 1.0 m apart. Plants within a row were thinned approximately 0.3 m apart on Jun 20, 11, and 15 in the 3 years, respectively. Cultural practices (such as fertilizer applications, cultivations, irrigations, control of insects, etc.) were conducted as judged necessary.

On Monday mornings throughout each flowering season, all blooms were tagged that were open, would open later that day, or had opened the previous day. Tagging was started on Jul 29, 28, and 27 in 1968, 1969, and 1970, respectively. Tags were coded so bolls from specific tagging dates could be differentiated at the end of the season, and records were kept of blooms tagged/row for each tagging date.

Harvesting was conducted after frost on Nov 23, 22, and 20 in the 3 consecutive years; and bolls for each tagging date from each row were kept separate. Counts of bolls set/row were made with a boll considered set if it had one or more locks of fluffy seed cotton. Percentages were then calculated of the tagged flowers/date which had set mature bolls. The seed cotton from each row and tagging date was ginned separately on an 8-saw, laboratory-type gin. Fiber samples were analyzed in the Fiber Laboratory at Oklahoma State University for 2.5 and 50% span length on the digital fibrograph in inches, uniformity index as the ratio of 50 to 2.5% span length expressed as a percentage, fiber coarseness on the micronaire in μg/inch, and 1/8-inch gauge fiber strength on the stelometer in g/grex. (Grams/grex equals g/decitex which equals 0.1 g/tex.)

There were seven tagging dates in 1968 and 1970 and six in 1969. The plants in 1969 were a week earlier in physiological maturity; and although tagging was started each year on the same calendar date (plus or minus a day), blooming was well underway at the first tagging in that year. In 1968 and 1970, blooms on the first tagging date were very few. Considering the stage of plant growth, the first tagging date in 1969 was judged equivalent to the second date in the other 2 years. To prevent possible bias in the statistical analyses as the result of an unbalanced design (and to simplify the analyses), the first tagging date in 1968 and 1970 was eliminated for all characters studied. Since blooms on the first date in those 2 years were sparse, little data were discarded; and loss of information was minimal.

When determining fiber properties in the laboratory, most samples did not have sufficient fiber from the last tagging date (i.e., date 7) for readings to be obtained. Therefore, statistical analyses of fiber properties were conducted for dates 2 through 6, inclusive. The boll retention characters (i.e.. number of blooms tagged, NBT; number of bolls set, NBS; and percentage bolls set, PBS), were compared for dates 2 through 7. In the analyses of NBT, NBS, and PBS, the four original subsamples/plot (i.e., rows/plot) were estimated separately; but since many of the subsamples did not have sufficient fiber for laboratory measurements, plot means of available subsamples were used in the fiber property analyses.

The data were analyzed as a split-plot design with tagging dates as subplots. In the F-tests among mean squares, year effects were considered random with the effects of cultivars and tagging dates as fixed.

RESULTS AND DISCUSSION

Boll Retention Traits

Table 1 includes analyses of variance for the boll retention traits. All main effects for the three characters were significant at the 0.05 probability level, except the dates mean squares for NBT and NBS. Those two mean squares were significant at the 0.10 level. The years × cultivars mean square was significant only for NBT while the cultivars × dates interaction was significant for NBS. The years × dates and second-order interactions were significant for all three characters. A significant experimental error for NBS indicated that this trait contained variation in addition to that among subsamples. The two error terms were not significantly different for NBT and PBS.

Mean performance over years is shown in Fig. 1 for NBT by cultivars and tagging dates. NBT gradually increased until slightly past the middle of the flowering season and then declined. This distribution pattern agrees in general with previous investigations (6, 8, 9). When inspecting such figures for separate years (not shown), we obtained the impression that the distribution for NBT tends in general to be a fairly symmetrical curve capable of being shifted as a unit to either earlier or later in the year depending upon the onset of environmental conditions favorable for flowering.

Westburn (Fig. 1) exhibited the highest mean NBT over all tagging dates except date 7. Lockett 4789-A performed well for NBT the first half of the bloom period and then rapidly declined, indicating considerable determinacy in maturity. Stoneville 7A took longer to reach the level of bloom production of Westburn; but once it did so, it was equivalent to Westburn throughout the remainder of the season. Overall, Verden exhibited the lowest level of NBT, particularly at the intermediate tagging dates. During the last dates in the season, Lockett 4789-A had fewer blooms. The distributions for Verden, Kemp, and Lankburn were

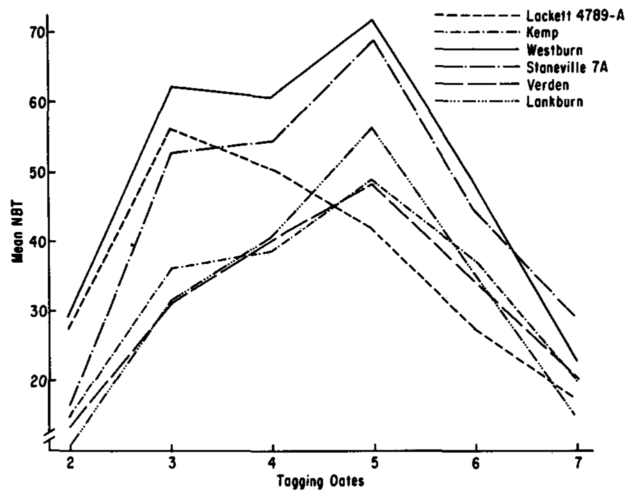

Fig. 1. Mean performance over years for number of blooms tagged (NBT) by cultivars and tagging dates.

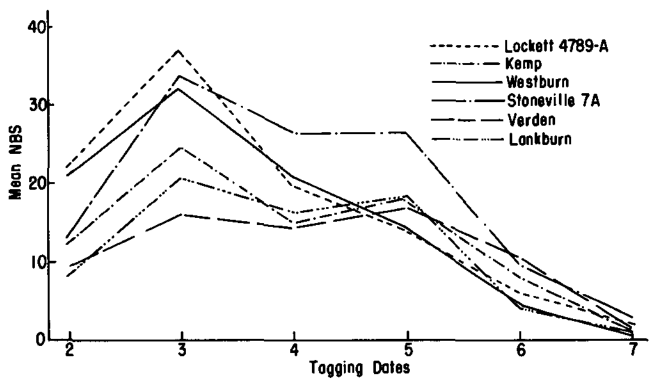

Fig. 2. Mean performance over years for number of bolls set (NBS) by cultivars and tagging dates.

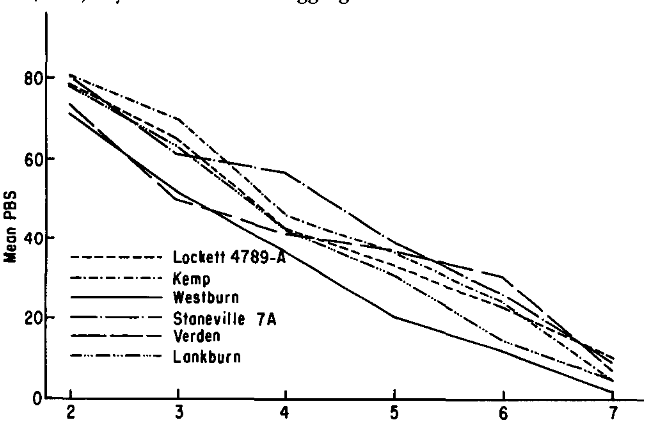

Fig. 3. Mean performance over years for percentage of bolls set (PBS) by cultivars and tagging dates.

very similar. The maximum NBT occurred on date 5 for all cultivars except Lockett 4789-A which had peaked 2 weeks earlier on date 3.

Mean performance over years for NBS by cultivars and tagging dates is presented in Fig. 2. Over cultivars, NBS increased to a maximum on date 3 (earlier in the season than for NBT); and after that point, it exhibited a fairly continuous decline to the end of the season. This clearly indicates that setting of blooms as bolls is more effective in the early part of the season. After 2 to 3 weeks of blooming, the absolute number of blooms set began, in general, to decline. A disproportionate drop in NBT (Fig. 1) and NBS (Fig. 2) can be detected for the actual means of some cultivars at date 4 below those estimated by interpolation between dates 3 and 5. The decrease in mean NBT was caused by a significant drop in bloom number on that date in 1968. The probable cause or causes are unknown as neither rainfall, maximum or minimum temperature, nor irrigation had an obvious influence on (or within 1 to 2 weeks prior to) that date of tagging in that year. The decrease of mean NBS on date 4 can be attributed to the fewer NBT on that date in 1968.

The peak date for NBS for all cultivars (except Verden) was on date 3, relatively early in the season. Lockett 4789-A, Westburn, and Stoneville 7A exhibited the highest NBS over the first half of the blooming period; Lockett 4789-A and Westburn then rapidly declined in NBS while Stoneville 7A persisted at a high level, thereby setting considerably more bolls through the remainder of the flowering season. Verden performed poorly for this trait, particularly in the first half of the season.

The overall trend for mean PBS (Fig. 3) is in general linear, showing a steady decrease throughout the flowering period regardless of cultivar. The corollary to the continuous decline in PBS is that shedding rate increases steadily throughout the season since an inverse relationship exists between those two characteristics. This general conclusion agrees with that of Buie (6). In 1970 (not shown), there was a pronounced drop in PBS on dates 4 and 5. A comparatively large number of blooms were available for tagging on those dates, but NBS did not increase proportionately. This drop in PBS can be attributed at least in part to a period of very high temperatures 7 to 10 days earlier in the season. In 1968 (not shown), a slight increase in PBS on date 4 was evident over cultivars. This increase is noteworthy because (as previously discussed) this was the tagging date at which a reduction in NBT and NBS occurred. The increase, therefore, implies that the difference in observed NBS on date 4 from the expected NBS (interpolating between dates 3 and 5) was not due entirely to a lower NBT. Had this been true, the observed NBS would have been still lower. The increase in PBS suggests that the plants were able to partially compensate for the scarcity of blooms by an increase in boll set efficiency.

In general, as the season progressed, PBS decreased; however, differences in PBS were noted among cultivars. Westburn showed a particularly rapid decrease in PBS; it was the lowest cultivar at all tagging dates except one. Even at that date, it was not significantly higher at the 0.05 level than the cultivar lowest in PBS. Stoneville 7A and Kemp performed well for this character, with Lockett 4789-A approaching them in efficiency of boll set over all tagging dates.

The basic relationship among the boll retention characters by tagging dates is summarized in Fig. 4 over years and cultivars. The fairly symmetrical curve with a peak at date 5 for NBT, the earlier peak at date 3 then decline for NBS, and the continuous decline in PBS over the flowering season are the major points to be noted.

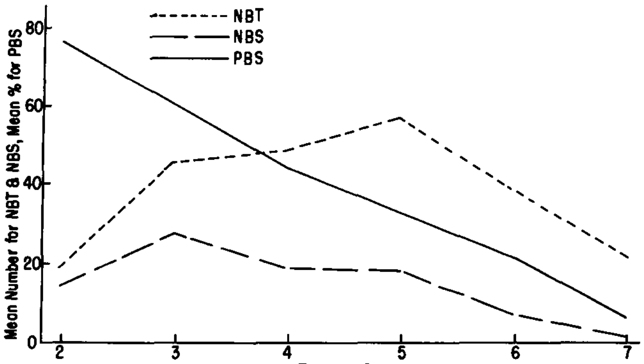

Fig. 4. Mean performance over years and cultivars for NBT, NBS, and PBS by tagging dates.

Fiber Length Characters

Results for 2.5% span length (2.5% SL), 50% span length (50% SL), and uniformity index (UNIF) are reported in this section. Analyses of variance for the three traits are shown in Table 1. All main effects were significant except the years mean-square for 2.5% SL and the dates mean-square for UNIF. All first-order interactions were significant except for the years $\times$ cultivars and the cultivars $\times$ dates mean-squares for UNIF. However, the second-order interaction was significant for that trait, but not the others.

Mean performance over years for 2.5% SL by cultivars and tagging dates is shown in Fig. 5. Regardless of cultivar, the 2.5% SL means over years exhibited a rather steady decline as the flowering season progressed. Although interactions between cultivars and dates are obviously present for this character, few changes in rank occurred among cultivars from one date to the next. In 1968 (not shown), the mean response over cultivars for this trait exhibited a loss on date 3, a rise on date 4, and a subsequent decline throughout the remainder of the season. In 1969, there was an increase through date 4, then a decrease. In 1970, there was an increase at date 3 followed by a constant recession except at date 6. In summary, moderately different patterns were exhibited by this character in each of the 3 years. However, the general decrease of 2.5% SL over years as the flowering seasons progressed is in agreement with most previous reports (4, 12).

Stoneville 7A had the longest 2.5% SL while Kemp had the shortest. The fiber lengths for Lockett 4789-A and Lankburn were quite similar, but shorter than Stoneville 7A. Verden exhibited a longer 2.5% SL than did Westburn which, in turn, was longer than Kemp over all tagging dates.

The mean performance for 50% SL over years by cultivars and tagging dates is provided in Fig. 6. Like 2.5% SL, 50% SL showed a general decline over the flowering season; and differences in ranking among cultivars between dates were infrequent. The mean performance for 50% SL in 1968 over cultivars (not shown) followed the same pattern as did 2.5% SL in the same year. This was not surprising since the factor or factors which influence fiber length should have at least a similar effect on different measures of the trait. In 1969, the patterns were again similar, with the tagging date for maximum length of 50% SL also

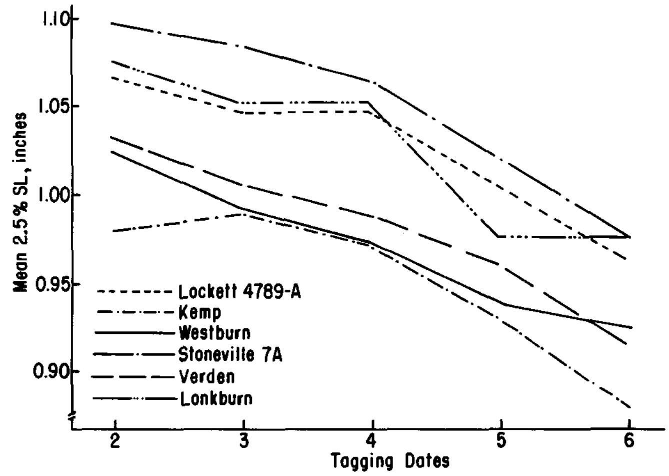

Fig. 5. Mean performance over years for 2.5% span length (SL) by cultivars and tagging dates.

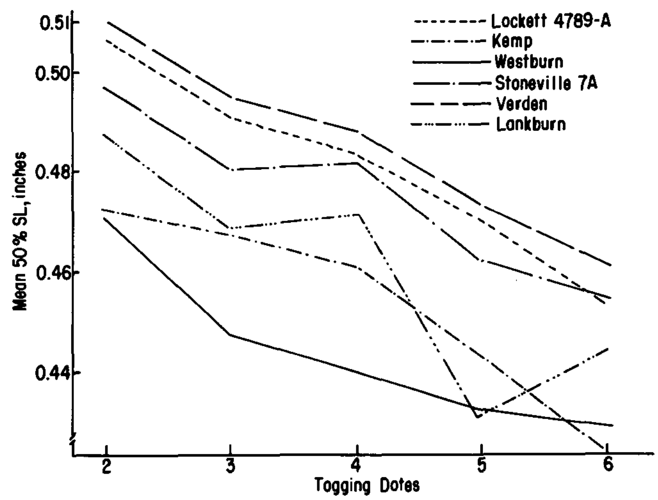

Fig. 6. Mean performance over years for 50% span length (SL) by cultivars and tagging dates.

being on date 4. The 1970 distribution for 50% SL did not increase on date 3 as it did for 2.5% SL; it decreased steadily through date 4 and then increased on dates 5 and 6. An increase for 2.5% SL was noted only on date 6. The pattern for 50% SL in 1970 for dates 2 through 5 was similar to the pattern for 2.5% SL in the same year for dates 3 through 6. This implies that approximately a week's delay was required in 1970 to obtain a response in the longer fibers comparable to that in the shorter ones.

Verden displayed the longest 50% SL over all dates while Westburn, in general, had the shortest. Lockett 4789-A was second longest while Stoneville 7A (the cultivar with the longest 2.5% SL) was third. Lankburn exhibited more pronounced interactions for this trait between dates than did the other cultivars.

Mean performance over years for UNIF by cultivars and tagging dates may be found in Fig. 7. All cultivars demonstrated a mean increase in UNIF on the last tagging date in the season above mid-season values. Several cultivars also had higher UNIF at the start of the season than at some of the intermediate dates. Very few changes in rank among cultivars were noted for this trait over dates. Except for a slight deviation

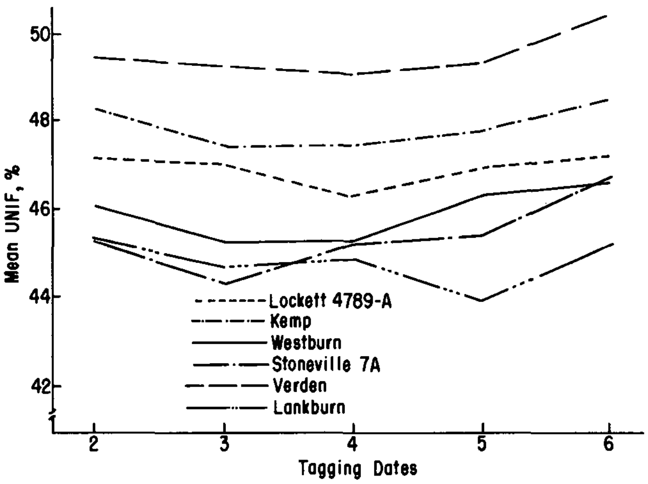

Fig. 7. Mean performance over years for uniformity index (UNIF) by cultivars and tagging dates.

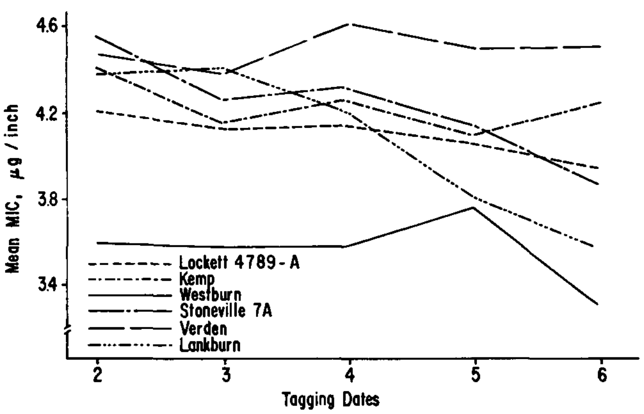

Fig. 8. Mean performance over years for micronaire (MIC) by cultivars and tagging dates.

on date 5, the 1968 distribution over cultivars (not shown) exhibited a gradual increase from dates 2 through 6. In the other 2 years, concave-type curves were in evidence. Although patterns between years were different to some extent, more uniform fibers were consistently produced at the end of the flowering period than through mid-season.

Among the cultivars in question, Verden had the most uniform fibers followed in order by Kemp, Lockett 4789-A, and Westburn. Lankburn and Stoneville 7A were very similar for UNIF at tagging dates 2, 3, and 4, but apparently differed at dates 5 and 6. Because Kemp had the shortest 2.5% SL among the cultivars tested, the reason for its high UNIF is not difficult to understand (i.e., a small denominator in the index ratio). Verden's high UNIF was obtained differently as it had the highest 50% SL (i.e., a large numerator).

Fiber Coarseness

All sources of variation for micronaire (MIC), except the years, dates, and cultivars × dates mean-squares, were significant (Table 1). Mean performance over years for this trait by cultivars and tagging dates is shown in Fig. 8. Except for Verden, MIC was lower for each cultivar in its end-of-season blooms than

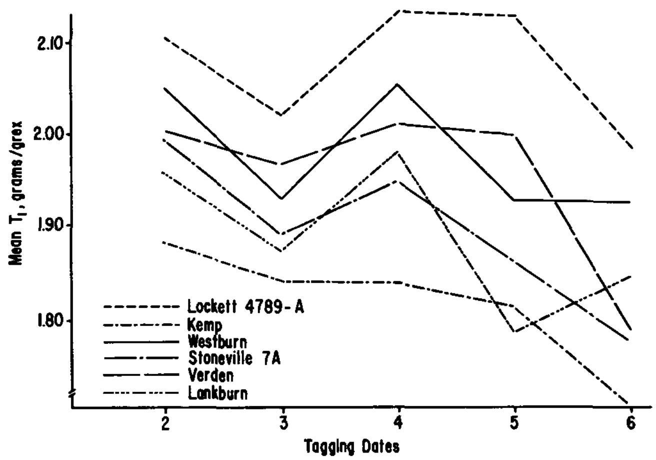

Fig. 9. Mean performance over years for stelometer (T_1) by cultivars and tagging dates.

in those from the beginning. Westburn had by far the finest fibers, while Verden had the coarsest. Several types of cultivar response were exhibited for this trait. Lankburn's MIC declined drastically over the season, Verden's increased, and Lockett 4789-A's remained essentially constant.

Fiber Strength

All sources of variation for 1/8-inch gauge stelometer (T_1) were significant except for the dates, years × cultivars, and cultivars × dates mean-squares (Table 1). The dates mean-square was significant at the 0.10 level. In Fig. 9, the mean performance over years by cultivars and tagging dates can be observed for this trait. In general, the cultivars showed a decline in T_1 toward the end of the flowering period. All cultivars exhibited an overall decrease on date 3 while all except one showed a subsequent increase on date 4. No explanation for the decrease at date 3 is readily apparent. After date 4, T_1 decreased the remainder of the flowering season.

Lockett 4789-A had the strongest fiber while Kemp had the weakest. Westburn and Verden were in a position slightly below Lockett 4789-A, while Stoneville 7A and Lankburn were generally intermediate between Westburn-Verden and Kemp.

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