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Effects of Fruit Load, Temperature, and Relative Humidity on Boll Retention of Cotton[1]

C. F. Ehlig and R. D. LeMert[2]

ABSTRACT

Climatological factors and the boll load from the first fruiting cycle were evaluated as primary causes for low boll retention by cotton (*Gossypium hirsutum* L.) during midseason. Boll retention was permitted from incipient flowering, or after June 26, July 15, July 30, or August 14, by the daily removal of flowers. Boll retention was greater than 75% initially, but decreased to less than 50% after bolls equivalent to 500 to 1,200 kg lint/ha (1 to 2 bales/acre) were retained and less than 20% after bolls equivalent to 700 to 1,300 kg lint/ha (1.25 to 2.25 bales/acre) were retained. The fruit load was the primary cause for low boll retention and cessation of flowering during midseason. No direct relationship between low boll retention and high maximum or minimum temperatures or high relative humidity was observed.

Additional index words: **Midseason cut-out, Solar irradiation.**

HIGH temperatures and high relative humidities are frequently cited as the primary causes for low boll retention by cotton (*Gossypium hirsutum* L.) during midseason in hot irrigated areas, such as the Imperial Valley. The growing season in the Imperial Valley is usually long enough to mature two fruiting cycles. Air temperatures during July and August are commonly 40 C or above at their maxima and 24 to 28 C at their minima. Relative humidities of 20 to 40% at the maximum air temperature and 60 to 90% at the minimum air temperature are also common. Relative humidity is even higher within the plant canopy than above the plant canopy.

Recent reports that high maximum or minimum temperatures and high relative humidities adversely affect flower fertility in cotton tend to substantiate these factors as the primary causes for the low boll retention during midseason. At Stoneville, Miss. Meyer (5) reported that the number of sterile anthers increased with increase in temperature above 38 C. A time interval of 15 to 16 days occurred between the high temperature and the expression of sterile anthers. At State College, Miss. Sarvella (6) showed negative correlations between male sterility in *Gossypium arboreum* cytoplasm and wind velocity, pan evaporation, and total solar irradiation in the 2 to 3 weeks before anthesis, whereas maximum and minimum temperatures showed positive correlations. Male-sterile stocks with *Gossypium anomalum* cytoplasm had positive correlations with temperature and total solar irradiation during the same period. In Arizona Fisher (3) has attempted correlating boll set of standard varieties with maximum and minimum temperatures. His best relationship on any one set of data was a negative correlation between boll set and minimum temperature with a 10-day lag time. With maximum temperatures of 38 C and minimum temperatures of 26 C, Hoffman and Rawlins (4) reported negligible boll set, because anthers failed to dehisce, at constant relative humidities of 21 and 90%. They observed good boll set at constant relative humidities of 40 and 65%.

The objective of the present experiments was to determine whether climatological factors or the boll load from the first fruiting cycle of the cotton plant was the primary cause for low boll retention during midseason by cotton varieties cultured in the Imperial Valley. In these experiments the fruiting structures were removed, at open flower, to different dates until as late as August 14. Subsequent boll retention was compared with climatological data collected at the weather station for the Research Center to differentiate between boll load and climatological effects on boll retention.

MATERIALS AND METHODS

Seeds of Deltapine 16[3] (DP 16) and Acala Imperial (AI) were planted in dry Holtville silty loam soil on beds with 1 m between centers and one seed row per bed. The varieties were tested separately because of their different growth habits. Irrigation water to initiate seed germination was applied on March 25 and 26, 1968.

Nitrogen, as NH_4NO_3, was broadcast and disced into the soil before bedding at a rate approximating 150 kg/ha and was sidedressed at a rate approximating 150 kg/ha on May 28. The seedlings were thinned to a spacing of 6 to 8 plants/m on April 28-30. Irrigation water was applied when plants showed moderate symptoms of water stress. Ten irrigations of 8 to 10 cm of water were applied, including the irrigation to initiate seed germination and an irrigation in mid-September to insure against a late-season plant water deficit. A regular program of insecticide application for pink bollworm (*Pectinophora gossypiella*) was initiated on August 1. This program was amended in September to control the cotton leaf perforator (*Bucculatrix thurberiella* Busck).

Plants were deflowered to progressively later dates to separate the effects of the boll load and high temperatures or high relative humidities on boll retention. Fruit retention was permitted from initial flower opening on June 3 or was prevented until June 26, July 15, July 30, or August 14 by hand removal of flowers on their date of opening. After these dates, open flowers were counted and tagged for later identification. Deflowering or tagging was performed daily, except Sundays. Flowers that opened on Sundays were removed or tagged on Mondays when they were distinguishable from flowers that opened on Mondays. Tagging and deflowering of all treatments, including a nonfruited control treatment, were discontinued after August 16 because the insecticide program prevented routine entry into the field. After the tagged bolls had opened, they were removed from the plants and identified as to date of flowering. Boll retention was determined for each date of tagging.

The experimental design for each variety was a randomized block with four replicates. The plots were selected for uniformity of stand and height in late May. Each plot was 4 m long and 1 row wide.

A test was conducted with the same varieties in 1969 to determine if physical handling of flowers during the tagging procedure induced boll retention that might not occur under normal conditions. Plants were permitted to set fruit immediately after first flowering, which occurred on June 2, or were deflowered until July 15 and then permitted to set fruit without further disturbances such as tagging. Cultural practices were similar to those in 1968.

[1] Contribution of the Imperial Valley Conservation Research Center, Agricultural Research Service, Western Region, USDA, Brawley, Calif. Received Dec. 23, 1971.

[2] Plant physiologist and agricultural research technician, respectively.

[3] Seed of DP 16 was kindly furnished by the Delta & Pine Land Company. Use of commercial names is for the convenience of the reader and does not imply a USDA recommendation.

Climatological data were obtained at the weather station for the Research Center. Temperature and relative humidity were recorded with a hygrothermograph in a standard weather bureau shelter. Solar irradiation was obtained with an Eppley pyrheliometer. This equipment was located about 0.7 km from the experimental cotton.

RESULTS AND DISCUSSION

Average daily boll retention for DP 16 was greater than 75% when plants were first permitted to set fruit (Fig. 1 to 5). After these initially high levels, the percent daily boll retention declined to very low levels as the plants became loaded with fruit. The percent daily boll retention in the treatments in Fig. 1 and 2 increased in late July and early August, but this was caused by a decrease in the daily flower production rate rather than an increase in the boll retention rate. Assuming an average of 50 bolls/m as equivalent to the production of 562 kg lint/ha (1 bale/acre), aver-

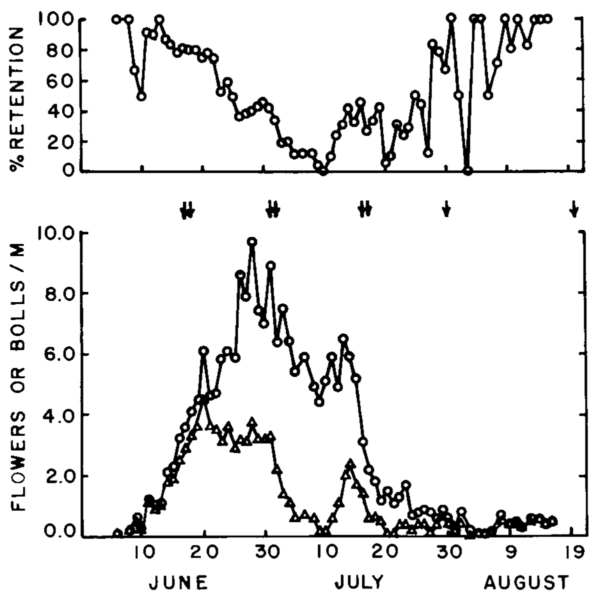

Fig. 1. Daily rates of flowering (O) and boll retention (Δ) and percent boll retention for DP 16 cotton permitted to set fruit from the initial date of flowering on June 3, 1968. Irrigation dates indicated by ↓.

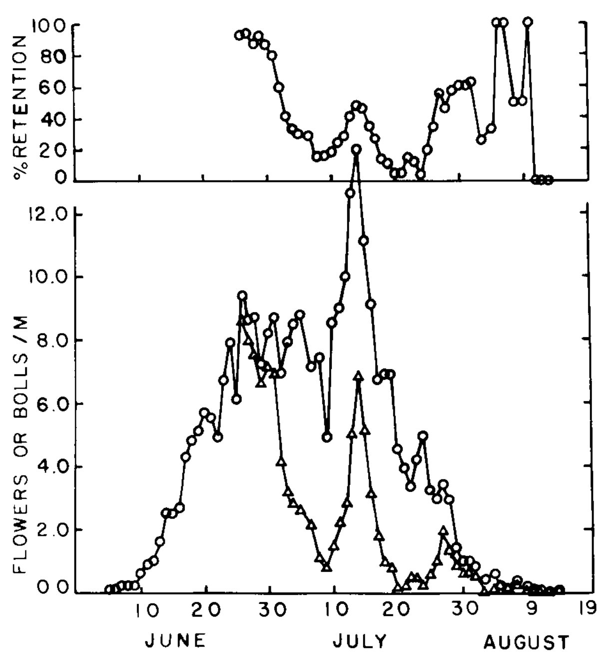

Fig. 2. Daily rates of flowering (O) and boll retention (Δ) and percent boll retention for DP 16 cotton deflowered to June 25, 1968 and then permitted to set fruit.

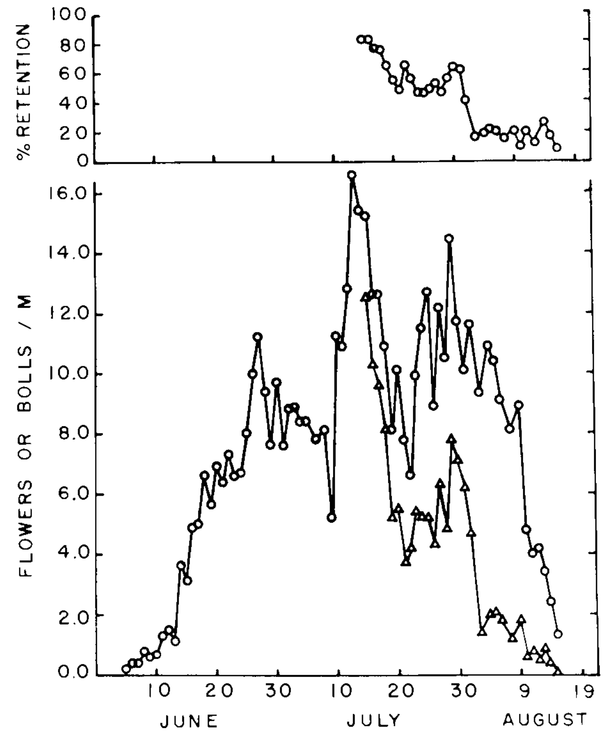

Fig. 3. Daily rates of flowering (O) and boll retention (Δ) and percent boll retention for DP 16 cotton deflowered to July 14, 1968 and then permitted to set fruit.

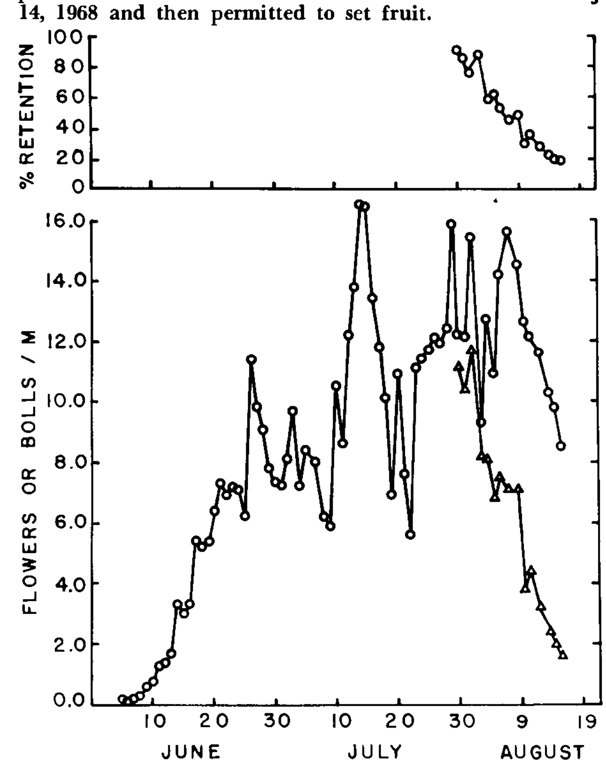

Fig. 4. Daily rates of flowering (O) and boll retention (Δ) and percent boll retention for DP 16 cotton deflowered to July 29, 1968 and then permitted to set fruit.

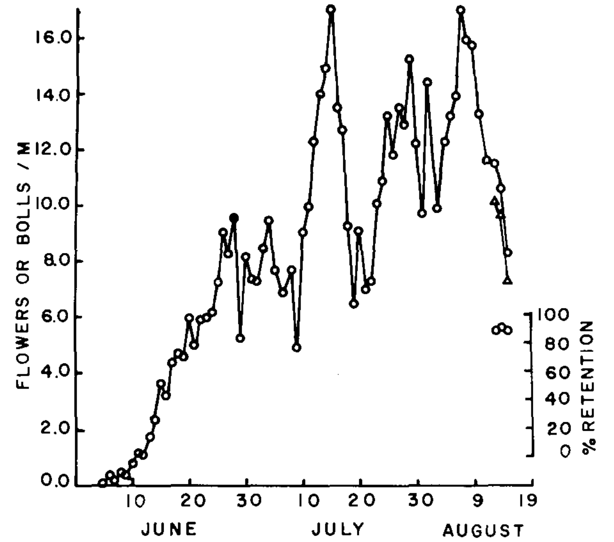

Fig. 5. Daily rates of flowering (O) and boll retention (Δ) and percent boll retention for DP 16 cotton deflowered to August 13, 1968 and then permitted to set fruit. Flowers were not counted or tagged after August 16 because of insecticide applications.

age daily boll retention was less than 50% after 500 to 1,200 kg lint/ha were retained and less than 20% after 700 to 1,300 kg lint/ha were retained.

A high negative correlation occurred between the percent daily boll retention and cumulative boll retention. The regression analyses, summarized in Table 1, were restricted to the first 30 days of boll retention on each treatment to avoid the effects of the maturity of early bolls on additional boll retention. This period was selected because other studies (2) indicated that bolls attained their maximum dry weight about 30 days after their flowers opened. The linear equations had negative slopes and had correlation coefficients of 0.71 to 0.93. These correlation coefficients were significant at P = 0.001. Quadratic or cubic equations generally fit the data better than the linear equations. The curvilinear regression lines more closely approximated the flatter slopes at low or intermediate values of cumulative boll retention

Table 1. Summary of regression analyses, by least-square method, of the percent daily boll retention (Y) as a function of cumulative boll retention (X). Bolls were included in the cumulative bolls on the date on which their percent retention was calculated.

Year	Treatment	Replicate	Linear regression: Y Intercept	Linear regression: Slope	r*
1968	Not deflowered, initial flowering on June 3†	1	92	-0.27	0.85**
		2	93	-0.23	0.93**
		3	97	-0.27	0.88**
		4	98	-0.25	0.86**
1968	Deflowered to June 25	1	92	-0.20	0.71**
		2	102	-0.24	0.83**
		3	106	-0.23	0.81**
		4	101	-0.25	0.87**
1968	Deflowered to July 14	1	89	-0.12	0.83**
		2	85	-0.12	0.83**
		3	83	-0.12	0.77**
		4	109	-0.17	0.87**
1968	Deflowered to July 29	1	90	-0.15	0.83**
		2	100	-0.18	0.88**
		3	108	-0.21	0.93**
		4	78	-0.11	0.82**
1969	Not deflowered, initial flowering on June 2†	1	121	-0.34	0.91**
		2	110	-0.33	0.89**
		3	108	-0.34	0.90**
		4	107	-0.29	0.91**

* r = coefficient of correlation. ** significant at P = 0.001. † During early June data were accumulated in daily increments for 2 or 3 days until at least 10 flowers were used in the calculation for the % of boll retention.

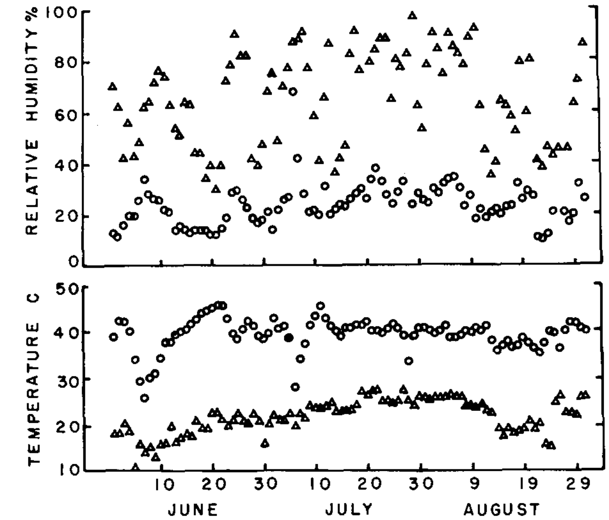

Fig. 6. Maximum (O) and minimum (Δ) temperature and minimum (O) and maximum (Δ) relative humidity during June through August 1968.

and the steeper slopes at higher values of cumulative boll retention. The decrease in the flowering rate was also related to the boll load as reported previously (1).

Temperatures and relative humidities during June-August 1968 are shown in Fig. 6. No direct relationship between low boll retention and high temperature or high relative humidity (Fig. 6) was apparent. A time interval of 1 to 3 weeks between the occurrence of high temperatures and the expression of low boll retention might have occurred, according to the references cited (3, 5, 6). In the treatments shown in Fig. 1 and 2 a period of low boll retention reached a minimum on July 9 or 10. This minimum boll retention occurred about 18 days after maximum temperatures of 40 to 45 C during June 14-22. However, a period of 18 days between the occurrence of high temperatures and low boll retention did not reconcile low boll retention at other times on these and the other treatments. Furthermore, neither high temperatures nor high relative humidity explained the continuously low boll retention after the plants had loaded with bolls or the decrease in flowering rate that occurred after the decrease in the rate of boll retention.

Plant adjustment to a period of low incident solar irradiation (Fig. 7) during July 3-7, with rain on July 5 and 6, may have caused the period of low retention that reached a minimum about July 9 and 10. Unknown factors responsible for the similar cycling of the flowering rate in all the treatments that were not in midseason cut-out may also have contributed to the unexplained fluctuations in the boll retention. Irrigation dates, as shown in Fig. 1, did not appear to contribute to the cycling of flowering or boll retention rates.

Data from AI were similar to the data from DP 16, except for slight differences related to genotype. AI had larger but fewer bolls than DP 16. Boll retention data for DP 16 rather than AI were presented, since DP 16 represented about 66% of the commercial plantings and 'Deltapine' genotypes represented more than 80% of the commercial plantings in the Imperial Valley. Yields of seed cotton from DP 16 were the same for all treatments deflowered to as late as July 30.

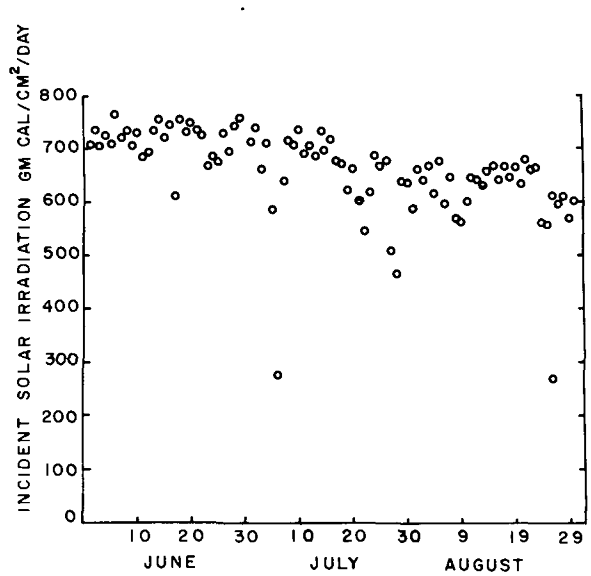

Fig. 7. Total solar irradiation, as measured with an Eppley pyrheliometer, during June through August 1968.

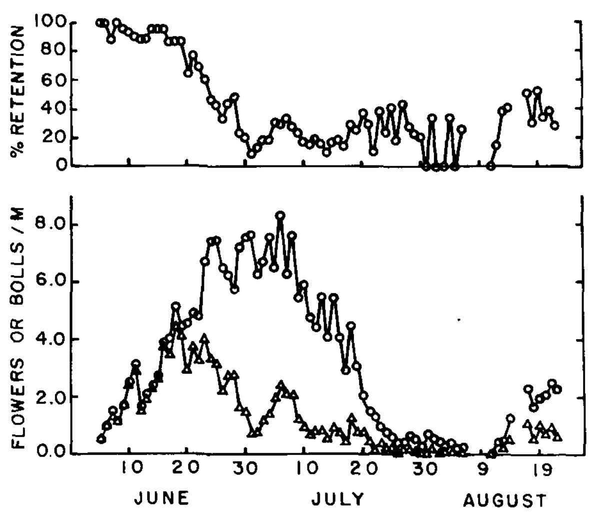

Fig. 8. Daily rates of flowering (O) and boll retention (Δ) and percent boll retention for DP 16 cotton permitted to set fruit from the initial date of flowering on June 2, 1969.

Yields of seed cotton from AI were the same for all treatments deflowered to as late as July 15. Average yields from these treatments were 0.41 kg seed cotton/m (2.7 bales lint/acre) and 0.49 kg seed cotton/m (3.1 bales lint/acre) for DP 16 and AI, respectively. Yields of both varieties decreased in treatments defruited to later dates. Cotton leaf perforators severely damaged the leaves of DP 16 in early September before they were controlled, but only slightly damaged the leaves of AI.

In 1969 air temperatures during the flowering stage did not reach or exceed 40 C until June 29, although such temperatures occurred on May 17, 18, 27, 30 and 31. Air temperatures during July and August were higher in 1969 than in 1968.

In 1969 flower production and boll retention by plants that set fruit immediately after flowering (Fig. 8) were very similar to 1968 (Fig. 1). The plants produced negligible flowers between July 20 and August 10. They retained very few bolls during July and early August. Their percent boll retention in July was very low until their flower production declined. As in 1968, a high negative correlation occurred between the percent daily boll retention and cumulative boll retention (Table 1). Plants that were deflowered until July 15, 1969 retained a good boll load by early August during the period when boll retention on the control plants was negligible. Data on boll retention and percent boll retention by plants that were deflowered to July 15 were unavailable. Such calculations require counting and tagging of bolls for later identification. Physical handling of the plants and flowers was purposely avoided during the period of fruit set to eliminate possible effects on boll retention. Since these plants fruited well at high temperatures without handling, the tagging procedure was apparently not a factor in boll retention during midseason in 1968. As in 1968, no relationship between boll retention and high temperature or relative humidity was apparent. Boll retention started to decline about June 26 before the maximum or minimum temperatures were excessively high.

Data from these experiments established that the boll load from the first fruiting cycle of the cotton plant was the primary cause for low boll retention and for low flowering (midseason cut-out) during midseason. When plants did not have a boll load, boll retention was high irrespective of the temperature or the relative humidity. Plants with a heavy boll load did not retain bolls even when the temperatures had been relatively low. Periods of high temperatures and high relative humidities often occur about the time the boll load is limiting boll retention. This may account for previous reports of relationships between boll retention and temperature. Our results do not preclude that extremely high temperatures might cause low boll retention of varieties currently grown in hot irrigated areas. The effects of high maximum or minimum temperatures on male-sterile lines may be the lower limit of a general temperature effect on sterility of cotton. In our fruiting studies in 1970 (2) boll retention was low on 2 successive days when maximum temperatures reached 46 and 49 C. Such high temperatures, however, do not normally occur continuously and therefore would not account for the periods of continuously low boll retention and flower production that occur in midseason.

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