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Abscission of Cotton Floral Buds and Bolls as Influenced by Factors Affecting Photosynthesis and Respiration[1]

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ABSTRACT

The effects of some environmental factors on abscission (shedding) of young cotton (*Gossypium hirsutum* L.) fruits were investigated because excessive shedding is sometimes a problem in cotton production. Increasing the concentration of CO_2 in the atmosphere from 350 to 1,000 ppm decreased shedding, increased the glucose and fructose contents of leaves. and lowered the average node number of the first bolls. Increasing the daily photoperiod from 8 to about 14 hours had similar effects. Conversely, shedding was increased by warm nights (30 C) and by low light intensity.

These results indicate that factors that decrease photosynthesis or increase respiration may delay fruiting and decrease retention of floral buds (squares) and bolls. Low light intensity could become critical with high plant populations (more than 100,000 plants/ha), cloudy weather, rank growth, or a combination of the above conditions.

Additional index words: **Carbon dioxide, Light intensity, Night temperature, Photoperiod, Shedding, Squares.**

MANY reports indicate that abscission of floral buds (squares) and young fruits (bolls) of cotton (*Gossypium hirsutum* L.) may be promoted by a deficiency of photosynthate. For example, shedding was increased by shading (3, 5, 6, 11), cloudy weather (8, 10), close spacing (2), and partial (5) or complete (10) leaf removal. Most of these results could have been due to factors other than, or in addition to, a deficiency of photosynthate. For example, cloudy weather is often accompanied by rain that can cause osmotic rupture of pollen and thus prevent pollination of open flowers. Close spacing could result in increased root competition or accumulation of ethylene in the plant canopy (9). Leaf removal could remove a source of auxin (4) or auxin precursors. Thus, additional tests seemed warranted on the effects of environmental factors that would alter the balance between photosynthesis and respiration.

In this paper the effects of CO_2 level, night temperature, photoperiod, and low light intensity on shedding of squares and bolls by young cotton plants are reported.

MATERIALS AND METHODS

Plant Culture. 'DPL 16' cotton seeds were germinated in moist vermiculite, selected for uniformity, and transferred to a modified Hoagland's solution of the following composition: 2 m*M* $Ca(NO_3)_2{:}4H_2O$, 1 m*M* $MgSO_4$, 1 m*M* KH_2PO_4, 5 m*M* KNO_3, 40 μM H_3BO_3, 10 μM $MnSO_4{:}H_2O$, 1 μM $ZnSO_4{:}7H_2O$, 0.4 μM $Na_2MoO_4{:}2H_2O$, 0.2 μM $CuSO_4{:}5H_2O$, and 15 mg/l $FeCl_3$ plus 10 mg/l Na_2EDTA or 25 mg/l technical sodium ferric diethylenetriamine pentaacetate. Plants were cultured in 12-liter containers, 4 plants to each of 10 containers on each 68 × 154 cm cart. No attempt was made to eliminate border effects. Solutions were aerated continuously and renewed weekly. Because of the nature of the treatments, replication was not feasible. However, data for each of the 40 plants per treatment were collected separately and standard errors of the means were used to estimate variability within each treatment.

CO_2 Level. Two tests were conducted in climate-controlled greenhouses in which atmospheric CO_2 was maintained at ambient (about 350 ppm) and at 1,000 ppm. CO_2 was monitored and regulated by an infrared gas analyzer. Plants in the first test were harvested as soon as the first squares reached the bloom stage, but plants in the second test were permitted to set some bolls before they were harvested. The tests were conducted from October 15 through December 9 and from December 8 through February 25. No supplemental lighting was provided. Temperatures were programmed by cam for a minimum of 20 C at 6 AM and a maximum of 35 C at 2 PM with gradual increases and decreases between the extremes.

Night Temperature. Plants were cultured in climate-controlled chambers with 12-hour photoperiods and a constant day temperature of 35 C and constant night temperatures of 20 or 30 C from January 6 to March 7. Incident light intensity was about 43,000 lux and was provided by equal numbers of sodium vapor and mercury-iodine vapor lamps. Plants were harvested shortly after they started blooming.

Photoperiod. Two tests were conducted on the effects of photoperiod on shedding, the first in growth chambers and the second in a climate-controlled greenhouse. Plants were cultured in growth chambers from March 8 to May 8 with 16-hour photoperiods or from March 8 to May 17 with 8-hour photoperiods; the long-day plants were harvested 9 days earlier than the short-day plants because they grew faster. Light intensity was about 43,000 lux, night temperature was 25 C, and day temperature was 30 C. The greenhouse test was conducted from June 29 to September 11 during which time the natural photoperiod decreased from 14.35 hours to 12.53 hours. Half the plants were moved from the greenhouse into the headhouse at 5 PM and back into the greenhouse at 9 AM daily to give an 8-hour photoperiod. Greenhouse temperatures were programmed by cam from a minimum of 20 C to a maximum of 35 C. The headhouse temperature was constant at about 25 C.

Prolonged Low Light Intensity. Plants were cultured in a greenhouse from January 2 to March 29. The daily maximum light intensity was about 108,000 lux except for a period of cloudy weather from March 10 through March 14 and March 23. Half of the plants were moved into the headhouse at 9 AM on March 21 and were kept there at about 650 lux until 3 PM, March 24, at which time they were moved back into the greenhouse. Except for a cloudy day, March 23, the controls received full sunlight and a natural photoperiod of about 12.2 hours during the treatment period. All plants were examined daily for abscising squares and bolls from March 23 until they were harvested March 29.

Measurements. All fruiting positions were examined on all plants. Numbers of squares, blooms, bolls, and abscised fruiting positions were recorded for each plant, and from these data the percentages of abscised fruiting positions (% abscised) were calculated. In addition, node number of the first retained boll was recorded in some tests, and sugar contents of leaves were determined.

Sugars were extracted from 200-mg portions of lyophilized leaves (that had been ground to pass a 40-mesh screen) in 50-ml stoppered centrifuge tubes. Much of the lipid fraction was removed by initially mixing the plant samples with 10 ml of a 1:4 (v:v) mixture of chloroform and ethanol for 15 minutes at room temperature. The samples were centrifuged and the supernatant fraction decanted into clean tubes. Five ml each of chloroform and water were added to the supernatant fraction to cause phase separation. The chloroform phase was discarded and the aqueous phase was saved. Sugars remaining in the de-

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fatted residue (pellet fraction) were removed by three successive 15-minute extractions with 70% ethanol at 80 C. The ethanolic extracts were combined with the aqueous residue from the first extraction and ethanol was then removed *in vacuo*. The samples were made to volume with water and residual lipids were removed with chloroform. Samples were freeze-dried and then silylated (12). Sugars were separated and quantitated by gas-liquid chromatography (GLC) on a 0.32 × 183 cm (1/8" × 6') column of 3% OV-1 on Chromosorb W (HP) 80/100 mesh (Pierce Chemical Co.)[3], using helium as carrier gas. The temperature program was 5 minutes at 140 C, 8 C per minute increase to 240 C, and then 10 minutes at 240 C.

RESULTS AND DISCUSSION

Treatments that should increase photosynthesis (high CO_2 level, long photoperiods, and high light intensity) decreased abscission of fruiting forms (Tables 1 and 2). Conversely, warm nights (which should increase respiration) increased abscission (Table 2). Furthermore, plants shed more in the growth chamber than in the greenhouse (Table 2), possibly because of lower light intensity in the growth chamber. Light intensities were about 43,000 lux in the growth chambers and reached a daily maximum of about 108,000 lux in the greenhouse. Shedding rates of greenhouse control plants varied with daylength; they ranged from 20.6% in September to 25.6% in February to 30.9% in December. A period of cloudy weather from March 10 through March 14 and a cloudy day on March 23 may have caused abnormally high shedding rates (37.7%) in the greenhouse control plants of the low-light stress experiment (Table 2).

[3] Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply its approval to the exclusion of other products that may be suitable.

Table 1. Effects of atmospheric CO_2 level on total fruiting positions (FP), on percentage of the total fruiting positions that abscised their fruiting forms (% abscised), and on number of squares, blooms, and bolls remaining at harvest (No. retained).*

CO_2 level	Total FP per plant	Percent abscised	Number retained per plant
First test:			
350 ppm	14.3±0.52	30.9±2.3	9.9±0.58
1,000 ppm	16.8±0.60	16.4±2.2	14.2±0.72
Second test:			
350 ppm	37.2±1.48	25.6±1.6	28.4±1.54
1,000 ppm	36.9±1.34	17.1±1.4	30.8±1.44

* Data are averages of 40 plants per treatment. Standard errors of the means are shown.

Table 2. Effects of night temperature, photoperiod, and 3.5 days at 650 lux on percentage of total fruiting positions that abscised their fruiting forms (% abscised) and on the number of squares, blooms, and bolls remaining at harvest (No. retained).*

Treatment	Growth chamber		Greenhouse	
	Percent abscised	Number retained per plant	Percent abscised	Number retained per plant
Night temperature:				
30 C	41.0±1.9	17.4±0.91	--	--
30 C	31.8±2.3	18.6±1.03	--	--
Photoperiod:				
8-hour day	48.6±3.0	11.0±0.71	31.8±3.5	24.2±1.55
Long day†	33.5±2.0	17.2±0.83	20.6±4.0	27.1±2.09
Low light stress:				
650 lux	--	--	62.8±2.9	12.8±1.25
Control	--	--	37.7±2.3	21.6±1.19

* Data are averages of 40 plants per treatment. Standard errors of the means are shown. † Long day was 16 hours for the growth chamber test and ranged from 14.35 to 12.53 hours for the greenhouse test.

Table 3. Abscission of squares and bolls as influenced by exposure to low light from 9 AM, March 21, to 3 PM, March 24.*

Date	Number of bolls		Number of squares	
	Control	Low light	Control	Low light
	Number abscised per day			
Mar 23 (cloudy)	1	3	0	0
Mar 24	1	16	0	1
Mar 25	1	14	1	3
Mar 26	1	15	1	5
Mar 27	3	13	0	7
Mar 28	7	15	4	27
Mar 29	9	20	10	117
Total abscised	23	96	16	160
Total remaining on plants	135	62	723	429

* These data are numbers of bolls and squares per 40 plants and not the average number per plant.

Subjecting plants to low light intensity greatly increased abscission of squares and bolls (Tables 2 and 3), which was in agreement with Dunlap's results (3). Boll abscission started before square abscission; bolls started abscising at an excessive rate 3 days after the start of the low-light treatment and continued to abscise after plants were returned to the greenhouse on March 24 (Table 3). Square abscission did not become excessive until about a week after the start of the test. Abcission of both squares and bolls continued even though the plants were returned to full sunlight on March 24. Apparently, the low-light stress triggered the abscission process and, once initiated, abscission was not prevented by returning the plants to full sunlight. Preliminary results indicate that low-light stress increased the evolution of ethylene by young bolls. Thus, the increased rates of abscission of squares and bolls may have been caused by an increased level of ethylene.

In addition to increasing retention of fruiting forms, high CO_2 level and a long photoperiod increased the concentrations of fructose and glucose in cotton leaves and lowered the position of the first boll (Table 4). Sucrose content, however, was hardly affected and may have been slightly decreased by the high CO_2 treatment.

Although the results reported in this paper do not provide information on the mechanism(s) by which abscission of squares and bolls was induced, they do agree with earlier reports in indicating that factors that increase net photosynthesis tend to decrease abscission. The influence of light intensity should be of special concern in view of the current popularity of high plant populations. Mutual shading could decrease light intensity in the lower part of the plant canopy to the point that photosynthesis would not be adequate to supply the needs of developing bolls. Brown (2) reported that shedding increased and buds, bolls, and total fruiting positions per plant decreased with

Table 4. Sugars in leaves and node number of first boll as influenced by CO_2 level and photoperiod.*

Treatment	Fructose	Glucose	Sucrose	First boll
	mg/g dry wt			node no.
CO_2 level:				
1,000 ppm	6.7±0.4	17.4±1.0	10.9±0.4	6.0±0.2
350 ppm	3.9±0.4	9.3±0.7	12.6±0.6	6.9±0.2
Photoperiod:				
Long day†	3.6±0.4	16.3±1.3	7.8±0.4	5.5±0.2
8-hour day	1.9±0.1	10.2±0.6	6.8±0.4	6.3±0.3

* Data are averages of 40 plants per treatment. Standard errors of the means are shown. † The long day ranged from 14.35 hours at the beginning of the test to 12.53 hours at the end.

increasing plant populations. The adverse effects of crowding were especially severe in the lower third of the plant canopy, where light intensity was lowest. Because developing bolls obtain most of their photosynthate from subtending leaves, bracts, and leaves one node removed (1), low light intensity in the lower part of the plant canopy would probably limit boll retention there.

A period of cloudy weather might stimulate additional shedding, depending upon boll load and the amount of mutual and self-shading. Ehlig and LeMert (7) recently reported very low rates of boll retention on July 9 and 10, after a period of cloudy weather during July 3 to 7. Goodman (8) found that plants with the heaviest boll loads were most likely to shed after cloudy weather.

A number of environmental factors would affect net photosynthesis and, thus, might influence square and boll abscission. These factors should be considered in predicting optimum plant populations.

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REFERENCES

1. Ashley, D. A. 1972. ^{14}C-Labelled photosynthate translocation and utilization in cotton plants. Crop Sci. 12:69-74.
2. Brown, K. J. 1971. Plant density and yield of cotton in northern Nigeria. Cotton Growing Rev. 48:255-266.
3. Dunlap, A. A. 1943. Low light intensity and cotton-boll-shedding. Science 98:568-569.
4. Eaton, F. M., and D. R. Ergle. 1953. Relationship of seasonal trends in carbohydrate and nitrogen levels and effects of girdling and spraying with sucrose and urea to the nutritional interpretation of boll shedding in cotton. Plant Physiol. 28:503-520.
5. ———, and ———. 1954. Effects of shade and partial defoliation on carbohydrate levels and the growth, fruiting and fiber properties of cotton plants. Plant Physiol. 29:39-49.
6. ———, and N. E. Rigler. 1945. Effect of light intensity, nitrogen supply, and fruiting on carbohydrate utilization by the cotton plant. Plant Physiol. 20:380-411.
7. Ehlig, C. F., and R. D. LeMert. 1973. Effects of fruit load, temperature, and relative humidity on boll retention of cotton. Crop Sci. 13:168-171.
8. Goodman, A. 1955. Correlation between cloud shade and shedding in cotton. Nature 176:39.
9. Heilman, M. D., F. I. Meredith, and C. L. Gonzalez. 1971. Ethylene production in the cotton plant (*Gossypium hirsutum* L.) canopy and its effect on fruit abscission. Crop Sci. 11:25-27.
10. Mason, T. G. 1922. Growth and abscission in Sea Island cotton. Ann. Bot. 36:457-483.
11. Saad, S. I. 1951. Studies on the physiology of the cotton plant. III. Effect of shading, defoliation, and debudding on development, flowering, and shedding of the cotton plant. Egypt. Acad. Sci., Proc. 7:59-74.
12. Sweeley, C. C., R. Bentley, M. Makita, and W. W. Wells. 1963. Gas-liquid chromatography of trimethylsilyl derivatives of sugars and related substances. J. Amer. Chem. Soc. 85:2497-2507.