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Ethylene Production in the Cotton Plant (*Gossypium hirsutum* L.) Canopy and Its Effect on Fruit Abscission[1]

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ABSTRACT

Using gas solid chromatography, ethylene was determined in excised plant tissue and in the atmosphere at midpoint of the mature cotton (*Gossypium hirsutum* L.) canopy in the field. The ethylene produced from excised tissue was: leaves, 1.2×10^{-9} moles/g; immature capsules, 0.35×10^{-9} moles/g; bolls, 0.07×10^{-9} moles/g; and pink blooms, 2×10^{-9} moles/g. The ethylene in the atmosphere at the midpoint of the cotton canopy was 3.6×10^{-12} moles/ml while the atmosphere surrounding an individual pink bloom contained 8×10^{-12} moles/ml ethylene. Ethylene was applied at rates of 9.3×10^{-12} and 18.6×10^{-12} moles/ml to fruiting field-grown cotton plants enclosed in plastic bags. A statistically significant increase in abscission of immature capsules and bolls was found for the 18.6×10^{-12} moles/ml-treated plants.

Additional index words: **Growth regulator, Fruit shed, Gas chromatography.**

NUMEROUS researchers (1, 4, 8, 11) have reported that ethylene caused cotton to abscise leaves, squares, bolls, and blooms. For example, Hall et al. (4) showed that exogenous ethylene caused rapid abscission of flower buds, flowers, and young cotton bolls (*Gossypium hirsutum* L.). The loss of these fruiting forms preceded leaf abscission.

Morgan and Gausman (8) and Morgan et al. (7) found that ethylene inhibited auxin transport in the cotton stems and petioles and affected the concentration of auxin in the abscission zone. Cotton plants treated with 2 to 10 μl of ethylene per liter of air defoliated extensively (5).

Abscission was shown to be the result of a complex interaction of endogenous ethylene, auxins, senescence factors, and possibly gibberellins (6). Abeles and Rubinstein (1) indicated a physiological role for the ethylene produced by tissue in response to both endogenous and applied auxins. Akamine (2) found that fading orchid flowers were emitting 3400 μl of ethylene per kg per hour when 97% of the bloom has faded.

The objectives of these experiments were: first, to determine the relative amounts of ethylene evolved by different plant tissues; secondly, to determine the difference in ethylene content within the plant canopy compared with the atmosphere surrounding the canopy; and thirdly, to determine if ethylene evolved within the plant canopy increased fruit abscission.

METHODS AND MATERIALS

Two sampling techniques for ethylene were used. The first involved weekly excision of fully mature leaves near the terminal as described by Namken (9). Excised leaves were immediately placed in 500-ml Erlenmeyer flasks and sealed. The flasks were placed in a portable insulated container, and immediately transported to a room with a constant temperature of 25 C. After 24 hours, 1-ml samples were removed from the sealed flasks and gas solid chromatography (gsc) was used for the quantitative determination of ethylene. The same technique was used for sampling blooms, squares, and young bolls periodically throughout the season. Three replications were used in the gsc analysis of excised tissue. The variety of cotton used throughout the test was 'Stoneville 7A' that was planted in rows 97 cm apart.

Secondly, field levels of ethylene were determined in the cotton canopy by sampling the air on three still nights between the hours of 2330 and 0200. Th free air within the canopy was sampled by slowly drawing air into 20-ml glass syringes which were immediately sealed by inserting the needles in rubber septa. Air samples were similarly taken at a distance of 0.2 cm from the white and pink blooms.

Ethylene (156×10^{-8} moles) was injected into sealed, double plastic tents (168,000 ml volume) covering mature, fruiting cotton plants and tightly tied with string at the base of the plant. In a subsequent experiment, twice this level (312×10^{-8} moles) was similarly applied to the cotton. Both the checks and the fumigated plants were covered with the tents. Before initiation of the abscission experiment, the fruiting forms (immature capsules and squares) were counted and marked with india ink, which had been previously tested to insure that it would not cause abscission. The immature capsules (small bolls) and squares present during the experiment could easily be identified by the marks. After 24 hours of contact between the exogenous ethylene and the cotton plant, the plastic tents were removed from both the check and treated plants and a fruit count initiated for determining abscission. Fruit drop was observed for 5 days following the removal of the tents.

Ethylene content was measured by gsc technique as described by Bayer (3). Activated alumina columns, 1/8 inch by 6 feet in size, in a Perkin-Elmer[3] 900 gas chromatograph equipped with dual flame ionization detectors were used for the analysis. Flows of 40 ml/min of helium with an oven temperature of 60 C, injectors 100 C, and manifold 140 C, provided a good separation for ethylene in a minimum of time. A pure ethylene standard was used for quantification.

RESULTS AND DISCUSSION

The relative amounts of ethylene evolved for a 24-hour period from excised plant tissues are shown in Fig. 1. The flower at pink bloom released the greatest amount of ethylene, 2.0×10^{-9} moles/g fresh weight. The leaves, large squares, and large bolls emitted 1.2×10^{-9}, 0.35×10^{-9}, and 0.07×10^{-9} moles/g fresh weight, respectively.

Table 1 shows the changes in ethylene production, as measured in the field, of a white bloom which turned within an 8-hour period into a pink, and then to a lavender bloom. The ethylene level varied from a low of 1.4×10^{-12} moles/ml to a high of 2.7×10^{-12} moles/ml. As these samples were taken directly from blooms in the field with varying environmental conditions, it could not be ascertained if these were true differences. Windspeed and temperature varied for this day but the changes in ethylene were not statistically correlated to these factors. The ethylene emit-

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[3] Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product listed by the U. S. Department of Agriculture.

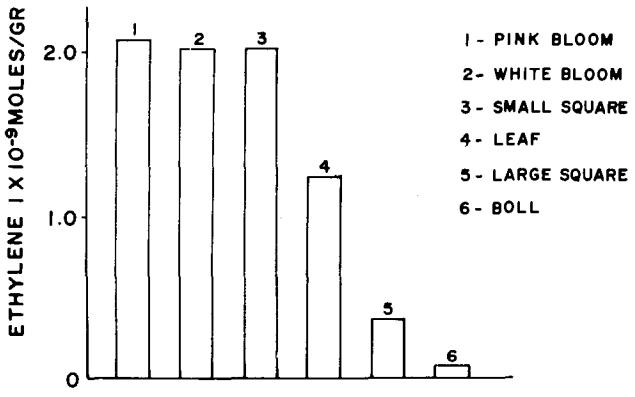

Fig. 1. Ethylene production by excised tissues of the cotton plant as measured 24 hours after excision, June 1969.

ted from the orchid flower, as reported by Akamine (2), changed with time. His data showed a progressive increase to a maximum at 34 hours and then a subsequent decline. The data indicate that ethylene does exist in the canopy for a diurnal period of time.

Assays of ethylene from samples taken at three different heights within the canopy are given in Table 2. Similar quantities and distribution of ethylene were observed in the canopy for the three nights studied. Ethylene in the center of the canopy was 3.6×10^{-12} moles/ml as compared with 0 and 3.3×10^{-12} moles/ml for the upper and lower surfaces, respectively. These data indicate the cotton canopies contained minute quantities of ethylene on calm nights.

Ethylene from pink blooms as measured on three separate nights averaged 8×10^{-12} moles/ml. This ethylene produced by the blooms, particularly during the calm nights which often occur during the fruiting period (10), is consistent with the hypothesis that ethylene released in the proximity of young, developing squares or immature bolls may accumulate to some extent and raise the internal concentration in the fruiting forms, thereby increasing the probability that they will abscise. For example, during the 1969 cotton growing season significant differences (55.6%) of the natural fruit which abscised were small immature capsules (Heilman, M. D., and C. L. Gonzalez. Unpublished data.)

When 9.3×10^{-12} moles/ml of ethylene was added to fruiting cotton in the plastic tents, abscission was 28.5 and 41.2% for the check and ethylene treatments, respectively.

The ethylene content of the atmosphere within the plastic tents averaged 6.8×10^{-12} moles/ml after 24 hours in the check tents as compared with 32.0×10^{-12} moles/ml after 9.3×10^{-12} moles/ml of ethylene was injected into the tents. The tents were removed from all plants after 24 hours. Doubling of ethylene content within the tents indicates the added ethylene stimulated production of ethylene by the plants. This increase had to come from the plants within the tents as the tents were sealed at the base of the plant by tying with string.

In another experiment, ethylene was injected into the tents at a concentration of 18.6×10^{-12} moles/ml. There was a significant ($P = 0.05$) difference between the accumulated natural fruit drop of the ethylene-treated plants compared with the check plants during

Table 1. Changes in ethylene production near a cotton flower.

Time	Ethylene production $\times 10^{-12}$ moles/ml	Flower color
7-16-69		
0830	2.4	White
1030	2.4	
1230	1.6	
1430	1.9	
1630	1.4	
1830	2.7	Pink
2030	2.7	
2230	2.7	
7-17-69		
0830	2.7	Lavender
1500	1.6	

Table 2. Levels of ethylene within a cotton plant canopy sampled at 2330 hours on July 10, 1969.

Canopy location	Distance above soil surface	Concentration $\times 10^{-12}$ moles/ml
	cm	
Upper canopy	99	0
Midcanopy	45	3.6
Lower canopy	15	3.3

Table 3. Fruit drop of cotton after a 24-hour exposure to ethylene added at a concentration of 18.6×10^{-12} moles/ml.

Plant	Number of fruit initially	% drop*
	Check	
1	25	20
2	34	29
3	16	44
	Ethylene treated	
1	29	48
2	48	50
3	28	71

* Ethylene was applied to mature plants on Sept. 24, 1969, the fruit dropped 5 days later was counted.

a 5-day period following the removal of the plastic tents (Table 3). The ethylene-treated plants abscised 25% more immature capsules and squares than did the check plants. An ethylene content $< 32.0 \times 10^{-12}$ moles/ml caused an increase in natural fruit shed. The lower limit at which ethylene could cause abscission is not clearly defined. The highest ethylene level to which a square or boll would be exposed would be in the near proximity of a pink bloom. This level of ethylene is definitely suspect for causing abscission as indicated by the trends of the first fumigation experiment.

The amount of ethylene contributed by individual leaves, squares, and bolls was not measured under field conditions because of the small amounts released by these parts. However, the results of the experiments, as presented in Fig. 1 for the exised plant tissues, indicate that blooms and leaves were potentially the largest contributors to ethylene contained within the canopy. Increase in ethylene concentration could not be detected in near proximity to leaves as was shown for the blooms. This does not, however, preclude the possibility that extremely small amounts per unit area are given off and could be significant contributors as indicated by the detached leaf data. From the bloom data, however, a gross calculation can be made of the production of ethylene released into the canopy. During the fruit-setting period (May 28 to July 25) the number of white blooms produced daily per acre ranged from 9,000 to 30,000, with an average of 14,900 blooms per acre. Ethylene was measured from white blooms and pink or lavender blooms which remained attached to the young developing boll for about 3 days. Therefore, the number of blooms contributing ethylene to the cotton canopy was approximately

45,000 (white and pink blooms) per day, resulting in a steady ethylene evolution of approximately 1.8×10^{-6} moles per day.

The results indicate that minute levels of ethylene could be one of the causes of square and young boll abscission. Intensive research is needed to find the desirable concentration and specific growth regulator which will retard abscission of cotton fruit. It is also possible that one of the advantages of certain cultural practices such as the skip row technique may be related to the reduced ethylene content of the canopy.

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