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Brief Articles

PHOTOSYNTHESIS, DIFFUSION RESISTANCE AND RELATIVE PLANT WATER CONTENT OF COTTON AS INFLUENCED BY INDUCED WATER STRESS[1]

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ABSTRACT

Frequent and simultaneous measurements of photosynthesis, transpiration, and relative plant water content were made on large cotton (*Gossypium hirsutum* L. 'Empire') plants. Measurements were made after adding polyethylene glycol to the nutrient solution to induce plant water stress. Reducing the solution water potential by 0.5, 1.0, and 2.0 bars had no observable effect upon the plant. The 4.0-bar treatment reduced photosynthesis, transpiration, and relative plant water content of a 97-day-old plant. The effect of the 4.0-bar treatment diminished as plant maturity increased and no residual effect of the treatment was detected after 48 hours of recovery in a standard nutrient solution.

Additional index words: Transpiration, Polyethylene glycol, Plant water relationships.

ANY effort to increase the efficiency of water use by plants must simultaneously consider transpiration and the factors that affect photosynthesis and plant growth. The diffusion resistance of the plant leaf is the only known rate-controlling parameter in the transpiration process that is subject to biological control. It is important, therefore, to understand the response of the diffusion resistance of plants to the environment and their internal water status.

The water status of a plant is dependent upon the soil water content but the dynamics of the relationship are relatively complex. Consequently, considerable interest has developed in the possibility of using osmotic substrates in nutrient solution to establish a predetermined and stable water potential around experimental root systems (Slatyer, 1961; Jarvis and Jarvis, 1963; Ruf, Eckert, and Gifford, 1963; Kaul, 1966; Lawlor, 1970). There is a consensus that polyethylene glycol (PEG) is only slightly diffusable and is probably the best osmotic substrate presently available.

The objective of the study herein was to determine the effect of PEG concentrations in the nutrient solution on the diffusion resistance, relative plant water content (Harris, 1971), and net carbon dioxide exchange of flowering cotton plants that were grown under constant environmental conditions.

MATERIALS AND METHODS

Plant Material and Cultural Practices. The test plant used for this study was cotton (*Gossypium hirsutum* L., 'Empire') adapted to the southeastern United States. Seedlings were started in vermiculite and transferred to an aerated modified Hoagland nutrient solution about 2 weeks after emergence. The plants were grown in this medium in a greenhouse until about 5 days before the start of an experiment. They were then transferred to a sealed, constant environment chamber where they remained until treatment application. The chamber was programmed for a 24-hour cycle of 12 hours of light and 12 hours of darkness. During the light period the chamber was maintained at 25±1C and

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Table 1. Amounts of PEG added to the standard nutrient solution to reduce the water potential.

PEG added	Reduction of water potential
g/liter	bars
00	0.0
58	0.5
85	1.0
128	2.0
189	4.0

40±5% relative humidity. At night, the chamber was maintained at 20±2C and 70±10% relative humidity. A combination of fluorescent (VHO) and incandescent lamps above a mylar barrier provided a light intensity of approximately 30,000 lux (0.26 cal cm^{-2} min^{-1}) in a plane 80 cm below the barrier. The carbon dioxide concentration was maintained at 310±10 ppm with an automated injection system.

The roots of a plant in the experimental chamber were immersed in approximately 38 liters of continuously aerated nutrient solution. Full-strength makeup solution was added each day to return the liquid to the original volume level. (A plant absorbed about 3 liters on an average day.) Once each week the entire solution was replaced with fresh solution. For a specific treatment, a PEG[3] solution was used for 24 hours. On these days at about 45 minutes prior to the start of the light period (time zero), the standard nutrient solution was replaced by the appropriate PEG solution, without causing physical movement of the roots. Thus, surface damage to the roots, which would have permitted PEG to enter the plant, was prevented.

Use of PEG to Reduce the Solution Water Potential. Three plants, designated I, II, and III, were used to evaluate the effect of PEG in the nutrient solution on the diffusion resistance (R), relative plant water content (RPWC), and net carbon dioxide exchange (NCO_2E) rate. These plants were all planted on the same day, and used consecutively, starting 87, 104, and 116 days after planting. Data not presented indicate that these plants had similar growth patterns.

Five PEG treatments were used on each plant. Table 1 gives the amounts of PEG added to the standard nutrient solution to reduce the water potential (Cox and Boersma, 1967). The schedule for applying the PEG treatments to plant I differed from plants II and III. Standard nutrient solution was used one or more days between each PEG treatment on plant I. For plants II and III, the 0.5, 1.0, 2.0, and 4.0-bar treatments were used on successive days. The exact schedule for each plant can be seen on Fig. 2.

Measurement Schedules of R, RPWC, and NCO_2E. Measurements for calculating R and RPWC were made at 2.5-minute intervals for a 750-minute period starting at the beginning of the light period. Data collection, therefore, continued for 30 minutes after the lights were turned off. A different procedure was used to estimate NCO_2E. One estimate per 50-minute period was made for 14 periods. The 15th period estimate was limited to a 20-minute interval which terminated with the end of the light perod.

Calculation of Total Diffusion Resistance. Gaastra (1959) estimated the diffusion resistance of individual excised leaves by measuring transpiration rates and estimating the vapor densities of water in both the stomatal cavities of the leaves and the surrounding air. A modification of this approach which utilized the total leaf area of intact plants was used to calculate the values for diffusion resistance reported here.

Data Collection. An integrating digital voltmeter and associated data acquisition system were used to record all data. Environmental parameters were sensed with standard transducers and leaf temperatures were measured with 5-junction thermopiles of 40-gauge copper-constantan wire. Transpiration and RPWC were measured by an automated double balance system (Harris, 1970). Records of carbon dioxide concentrations and injection amounts provided data for calculating NCO_2E. A scan frequency of once every 2.5 minutes was used for the period extending from 100 minutes before time zero to 45 minutes after the lights were turned off. A scan frequency of once every 15 minutes was used during the remainder of the dark period.

[3] PEG—Carbowax-6000, pharmaceutical grade, manufactured by Union Carbide Co., New York, N.Y. The citation of a trade name is not to be construed as official government endorsement of a commercial product.

RESULTS AND DISCUSSION

Data collected for 16 days in standard nutrient solution indicated that all plants in the test exhibited diurnal patterns of diffusion resistance, relative plant water content, and net carbon dioxide exchange. All plants appeared to remain relatively stable between 100 and 500 minutes of the light period. The lowest line in Fig. 1 illustrates the diurnal pattern for diffusion resistance. The existence of a diurnal pattern places restriction on the kinds of experimental designs that can be used and the presentation of data.

PEG in the Nutrient Solution on Plant Responses. The effect of the PEG treatments on the diffusion resistance of plant II is shown in Fig. 1. The 0.5 and 1.0-bar treatment data were omitted because they were essentially identical to the data for the "standard" day. The lines are computer plotted and each line is essentially a series of approximately 280 points connected by straight lines. The 4.0-bar treatment resulted in a higher R than all other treatments.

The effect of PEG on all three plants is given in Fig. 2. Average values of diffusion resistance, relative plant water content, and net carbon dioxide exchange are presented for five concentrations of PEG for each plant. All points are averages for the period extending from 100 to 500 minutes after time zero. The abscissa is plant age expressed in days after planting. Some general trends are indicated by the data plotted in Fig. 2. All PEG treatments of 2.0 bars or less had little or no effect on R, RPWC, and NCO_2E. The 4.0-bar PEG treatment definitely affected the R, RPWC, and NCO_2E, but the magnitude of the effect decreased as the plant aged. For plants I and II, the RPWC declined and the R increased on the days of the 4.0-bar PEG treatments. This suggests that the primary effect of the PEG was to re-

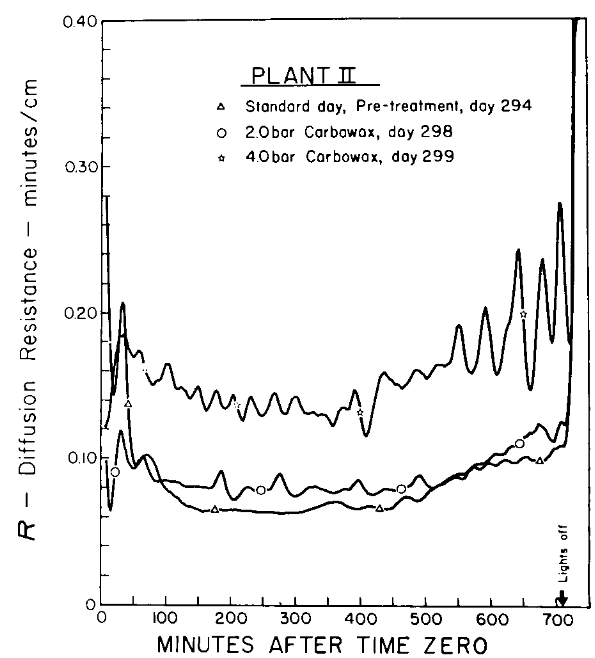

Fig. 1. Diurnal patterns of diffusion resistance for plant II as influenced by three concentrations of polyethylene glycol.

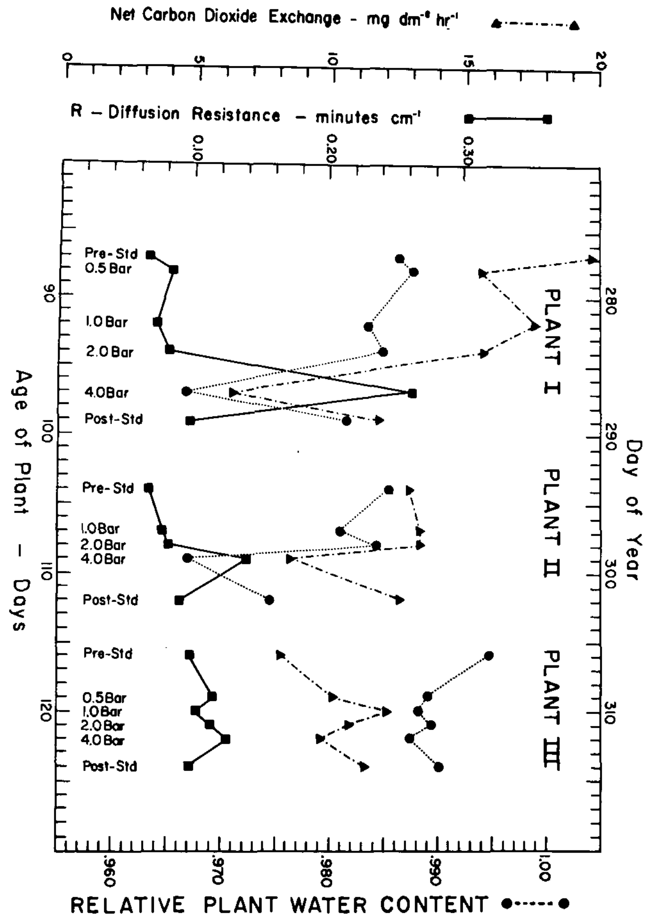

Fig. 2. Average daily diffusion resistance, relative plant water content, and net carbon dioxide exchange for three cotton plants as influenced by five concentrations of polyethylene glycol. (All averages restricted to periods 3 to 10.)

duce absorption of water into the plants. The absorption was probably reduced by either a reduced root permeability or a decrease in the potential gradient between the nutrient solution and the xylem; also, these two effects could possibly have acted in combination. Alternating 30-minute periods of light and darkness to dehydrate and rehydrate the plant could be used to evaluate the effect of the PEG on root resistance.

The effects of the PEG treatments on NCO_2E were similar to the effects on RPWC. The responses of all three parameters plotted in Fig. 2 are consistent with the hypothesis that PEG can be used to simulate the effect of decreased soil water potential.

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EVALUATION OF INTERGENOTYPIC COMPETITION WITH A PAIRED-ROW TECHNIQUE[1]

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ABSTRACT

A paired-row technique was developed to measure intergenotypic competition between soybean (*Glycine max* (L.) Merr.) cultivars. A paired-row plot consisted of two rows spaced 8 cm apart, the closest that we were able to grow soybeans in Iowa and still distinguish the individual rows at harvest. Different paired-row plots were grown 1 m apart. To evaluate the competitive interaction of two soybean cultivars, three paired-rows are needed per replication, one where the cultivars compete and one for each of the two cultivars in pure stand.

Intergenotypic competition in paired-rows was compared with that in a 1:1 blend grown in a single-row plot for nine cultivar pairs. A cultivar with tawny pubescence and a cultivar with gray pubescence were selected for each blend to permit separation of the cultivars at maturity. The individual cultivars were harvested separately in both the paired-rows and the 1:1 blend, and their yield performance was compared with that in a pure stand.

The paired-row technique was effective for determining the good and poor competitors in a blend for every cultivar pair tested. The percentage yield increase or decrease of each cultivar in competition generally was similar in the blend and the paired-rows. The data suggested, however, that growing cultivars in rows only 8 cm apart did not perfectly simulate the competitive interactions that occur in a 1:1 blend.

***Additional index words*: *Glycine max* (L.) Merr., Soybeans, Heterogeneity, Blends, Seed yield, Plot technique.**

CULTIVARS of soybeans (*Glycine max* (L.) Merr.) differ in their competitive ability when grown in a mixture or blend. Brim and Schutz (1) have shown that overcompensation can occur when certain pairs of soybean genotypes are grown together in a competitive situation. With overcompensation, the yield decrease of one competing genotype is less than the yield increase of the other genotype, and there is a net gain in yield of the mixture. Brim and Schutz (1) developed a prediction equation to estimate the performance of mixtures of soybeans cultivars. Use of the equation requires an estimate of the competitive interaction of the cultivars being evaluated.

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