

Chapter 8

SOURCE-SINK RELATIONS AS AFFECTED BY WATER STRESS DURING BOLL DEVELOPMENT

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INTRODUCTION

Cotton (*Gossypium hirsutum* L.) like most agronomic seed plants produces photosynthate in green leaves (sources) and then exports some of the assimilate photosynthate to other tissues (sinks) that are not capable of self support. In addition, cotton, having an indeterminate growth habit, has both vegetative and reproductive growth occurring simultaneously during a large portion of its life cycle. Numerous studies have described leaf development and associated photosynthetic activity of the cotton plant, transport of the assimilate to various sinks, and utilization of the assimilate by that sink. In general, during leaf development, photosynthetic activity increases to a maximum rate about 20 days after unfolding, maintains a high rate for a relatively brief period of time (10 to 20 days) and then declines as the leaf ages until senescence occurs (Muramoto *et al.*, 1967). Of the daily assimilate, the leaf retains a relatively high percentage for its own use, (Brown, 1968; Ashley, 1972). The exported assimilate is distributed to various sinks depending upon leaf type, position on plant and growth stage (Ashley, 1972; Brown, 1968, 1973).

After flowering, the developing boll receives assimilate from its associated bracts, the subtending leaf and the vegetative leaf subtending the sympodium (Ashley, 1972; Benedict *et al.*, 1973; Benedict and Kohel, 1975; Brown, 1968, 1973). As the plant develops, closure of the canopy increases the shading associated with bolls on the lower sympodia. Photosynthetic activity is greatly reduced in the leaves primarily associated with the developing bolls in the lower canopy. The bolls then receive assimilate from upper canopy leaves on the same side of the plant (Brown, 1973).

RESPONSE TO WATER STRESS

It is widely recognized that plant productivity is adversely affected by water stress. Although cotton is not considered to be a highly drought resistant plant, it is often grown in environments where water stress commonly occurs. The plant response to water stress is very dependent upon timing, rate of development, intensity, and duration. Our program has been largely concerned with developing an understanding of the effects of water stress on the production and utilization of assimilate during the boll development period. We specially want to know whether the stress is directly affecting the source or the sink. Experiments have been conducted under both field and glasshouse conditions.

SOURCE RESPONSE

Source activity is a function of effective leaf area times the photosynthetic rate per unit leaf area. Relatively moderate water stress reduces whole plant leaf area of cotton largely through reductions in leaf numbers rather than through reductions in leaf size (Table 1). Main stem leaf numbers were reduced only 10 percent (22 nodes versus 20 nodes); however, sympodial leaf numbers were greatly reduced. The reduction in leaf number was due to reduced initiation rather than loss of existing leaves through senescence. Photosynthetic rate per unit leaf area began to be significantly affected when the leaf water potential declined from a mid-day value of -20 bars (Figure 1). The reductions in photosynthetic rate, when coupled with the reductions in leaf area, resulted in significant reductions in whole plant assimilation rates. Leaf age effects on photosynthetic rates were evident at equivalent irradiance and temperature conditions similar to the results of Muramoto *et al.* (1967).

Individual source leaves retain a significant proportion of their daily assimilate for their own use (Chapter 22). Twenty two hours after exposing individual leaves to $^{14}\text{CO}_2$, as much as 40 percent of the initially incorporated ^{14}C remained in the leaf (Table 1). Significant differences were observed due to stress with only minor differences due to leaf position within the canopy when retention is expressed as a percentage of daily assimilation. However, on the basis of leaf dry weight, significant differences were observed between young tissue and older tissue, reflecting differences in growth and maintenance functions. Additionally, water stressed leaves consistently retained a higher amount of the daily assimilate per unit dry weight, suggesting maintenance costs may be increased.

The rate of disappearance of the ^{14}C from the treated leaf was used to estimate translocation of assimilate from the leaf (Figure 1). In C_3 plants ^{14}C loss with time after exposure reflects not only translocation but also photorespiration losses. Our efforts do not indicate that water stress affects photorespiration directly, and thus the differences in ^{14}C loss from treated leaves reflects an effect of water stress on

the translocation rate. Expressing the loss of ^{14}C as a function of that initially assimilated resulted in an effect due to water stress as the leaf water potential declined from -22 or -23 bars (Figure 1). As previously stated, the photosynthetic rate was affected by stress resulting in leaf water potentials of -20 bars. The

Table 1. Source-sink activity of cotton as affected by water stress during boll filling.

Plant parameter	Growth condition	
	Nonstressed	Stressed
I. Leaf area		
Whole plant	22 dm ²	10 dm ²
Single blade	.48 dm ²	.37 dm ²
II. Leaf number		
whole plant	47	27
III. Avg. daily net photosynthetic rate (mg CO ₂ .dm ² .hr ⁻¹) (single leaf basis)	25	20
IV. Daily assimilate retained by leaf (%)	30	40
V. Bolls per plant	7	5
VI. Bolls/dm ² leaf area	.36	.50
VII. Boll dry weight (g lint/boll)	1.53	1.47
Nonstressed = irrigated plots	avg. $\Psi_L = -15$ bars.	
Stressed = dryland plots	avg. $\Psi_L = -20$ to -22 bars during boll filling period	

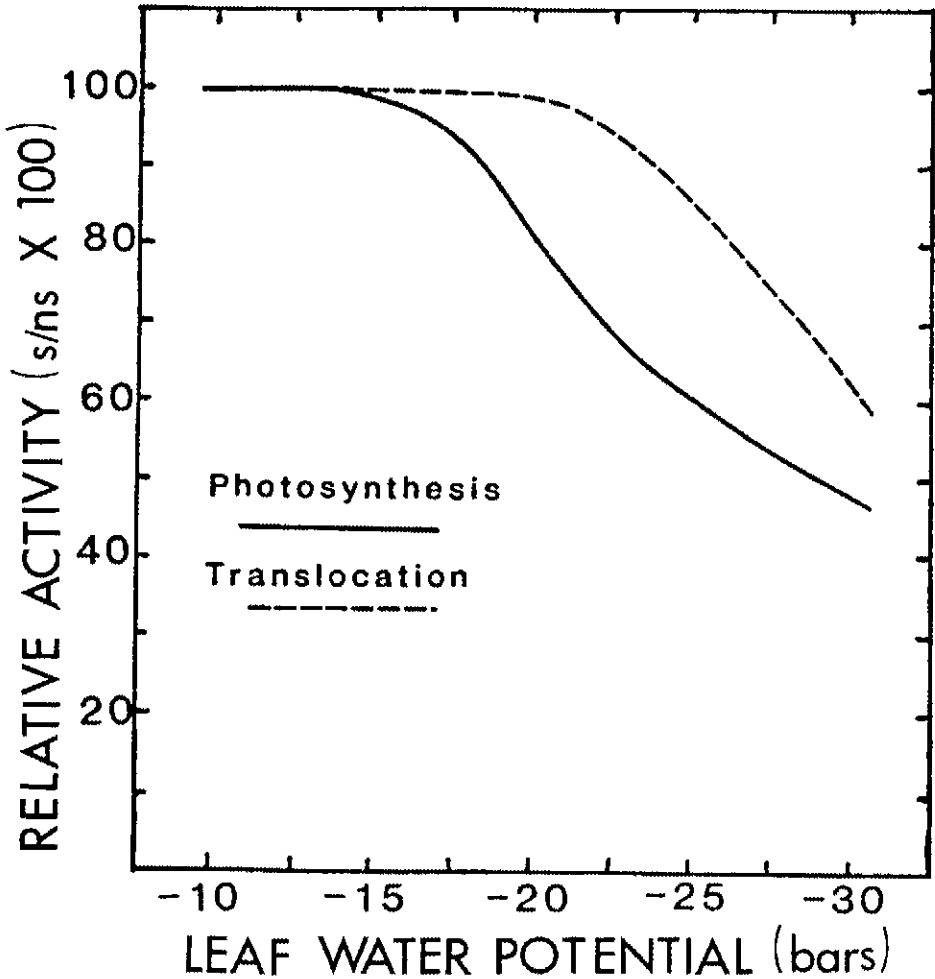


Figure 1. Relative activity of photosynthesis and translocation in cotton leaves as a function of leaf water potential. (s = stressed; ns = nonstressed)

translocation rate response would indicate that photosynthetic C assimilation is more sensitive than translocation.

SINK RESPONSE

The distribution of the exported ^{14}C was also examined 24 hours after exposure of various source leaves to evaluate changes in sink type or strength. The fruiting forms on the sympodium directly associated with the treated leaf received the greatest proportion of the exported ^{14}C . In all cases, water stress increased the

percentage of exported ^{14}C accumulated by the developing fruit. Upper canopy leaves on the main stem allocated a larger portion of the exported assimilate to vegetation and fruiting forms below the treated leaf; whereas, lower canopy leaves directed more assimilate toward the shoot than toward the roots. Water stress changed the allocation pattern for the upper canopy leaves but not for the lower canopy leaves.

The partitioning of assimilate within a sympodium was also examined. The boll attached to the first nodal position received the majority of assimilate produced by leaves on that sympodium. This boll was 25 days old, whereas the second boll was 18 days old and the third boll 8 days old. These data clearly indicate that the direction of assimilate flow is under the influence of sink strength. The pattern of assimilate flow was not affected by water stress.

Water stress imposed on the cotton plant after flowering began resulted in significant abortion of small fruit. Of the bolls produced, no significant differences in dry weights existed between non-stressed and stressed plants in this experiment (Table 1). Our data indicate that fruit load is manipulated so that the reduced amount of available assimilate can be utilized most efficiently. The intrinsic abortion mechanism is probably controlled by hormones (Heilman *et al.*, 1971); however, the decrease in photosynthetic productivity may trigger the hormonal changes (Guinn, 1974a; chapter 12).

SUMMARY

The results of these experiments suggest that the primary effect of water stress resides in reduced photosynthetic activity due to leaf area and photosynthetic rate reductions, confirming our previous work (Ackerson *et al.*, 1977). Some reallocation of exported assimilate from various source leaves is also apparent with the changes being associated with various sink strengths. The major effect was on source activity not sink activity.

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