DROUGHT TOLERANCE AND FOLIAR SPRAYS OF GLYCINE BETAINE

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Abstract

Water is the most limiting factor in cotton production, and numerous efforts have been made to improve crop drought tolerance. Field studies were conducted in 1998 and 1999 to determine if foliar application of glycine betaine would enhance yield in cotton under both drought and irrigated conditions. In 1998, glycine betaine treated plants had numerically, but not significantly (P=0.05) greater boll numbers, boll weights and lint yields. In 1999, yields were inconsistent, with glycine betaine generally having no effect. No differences in photosynthetic rate between treated and untreated plants were encountered either year of the study. In 1999, plant water relation trends suggested that glycine betaine might assist in osmotic adjustment.

Introduction

Water availability often exerts more pressure on the survival of higher plants than any other single environmental factor. Higher plants are usually faced with some degree of water stress during development (Morgan, 1984). Plants attempt to tolerate or resist stresses due to decreased water availability by making cellular osmotic adjustments through increases in inorganic ions or organic solutes (Hendrix and Pierce, 1983). Recently, the quaternary ammonium compound, glycine betaine, has received attention as a compatible osmolyte involved in drought tolerance (Agboma et al., 1997; Makela et al., 1996).

Glycine betaine has been exogenously applied to many crops that accumulate, or do not accumulate, glycine betaine in an effort to improve stress tolerance and yield. The effects of glycine betaine on plants during periods of inadequate water supply have been studied in maize and sorghum (Agboma et al., 1997), and cotton (Gorham, 1998). Results have varied, and appear to depend on numerous factors including type of crop, timing and rate of application, and environmental conditions. A preliminary field study was conducted in Fayetteville in 1998 to evaluate the effects of foliar-applied glycine betaine on cotton with a mild drought stress imposed two weeks after first flower (FF) (Meek and Oosterhuis, 1999).

The objectives of the 1999 field study were: (1) to evaluate the potential use of glycine betaine to enhance drought tolerance and yield in cotton, (2) to determine the optimal rate and timing of foliar application of glycine betaine to cotton for enhanced crop performance, and (3) to characterize long- and short-term responses between tolerant and sensitive cultivars treated with glycine betaine under both well-watered and water-deficient conditions.

Materials and Methods

Two field studies were planted in 1999 into a Dundee silt loam soil in early May at the Delta Branch Research Station in Clarkedale in northeast Arkansas. Pest control and fertilizer management was according to Arkansas cotton production recommendations . Plots consisted of 4 rows, 15.24 m in length spaced 0.97 m apart. Foliar sprays were applied with a CO_2 backpack sprayer calibrated to deliver 10 L of solution/ha. In both studies, a nonionic adjuvant was used.

Rate and Timing

In the rate and timing study, six replications of Suregrow 125 were arranged in a randomized complete block design, with no irrigation. Foliar applications began at FF and continued for four weeks. Treatments consisted of three rates of glycine betaine (2, 4, and 6 kg/ha) applied weekly, biweekly, or monthly, and an untreated control for a total of ten treatments.

Yield was determined from the middle two rows of each plot harvested with a mechanical picker. Boll weights and fiber quality were calculated based on four replications of 30 hand-picked mid-canopy bolls per plot.

Water-Stress and Cultivar

The water-stress and cultivar study consisted of six replications arranged in a split-split plot design. The three factors were (1) water: irrigated vs. nonirrigated, (2) foliar treatment: 4 kg/ha glycine betaine vs. adjuvant only, and (3) cultivar: Siokra L-23 (drought tolerant) vs. Stoneville 506 (drought sensitive). Treatments were applied at FF and FF + 2 weeks.

Physiological measurements were taken at 2, 4, and 6 weeks after FF. A LICOR 6200 portable photosynthesis system was used to evaluate photosynthetic parameters, and osmotic adjustment was monitored with thermocouple psychrometry (Oosterhuis and Wullschleger, 1989). Yield was determined from the inside two rows of each plot with a mechanical picker. Boll numbers, boll weights and fiber quality were assessed by hand-harvesting 2 m^2. Seed number, seed weight, and lint percent was also determined from hand-harvested samples.

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Results and Discussion

Several treatments had significantly higher boll weights compared to the untreated control plants (Table 1). Although not significant (P=0.05), plants treated biweekly with 2 kg/ha glycine betaine had the highest lint yield. All other glycine betaine treatments appeared to have lower lint yields when compared to the untreated control.

No significant differences (P=0.05) in yield components (Table 2) were observed between glycine betaine treated and control plants. The drought sensitive cultivar, Stoneville 506, had significantly (P=0.05) higher yields compared to the Siokra-L23. It is possible that Siokra-L23 is considered drought tolerant for survival, but increased yields do not necessarily occur.

No significant differences were observed in photosynthetic rates or osmotic potential (Table 3). Glycine betaine treated plants had numerically lower osmotic potentials, suggesting glycine betaine might enhance osmotic adjustment but this was not reflected in improved yields.

Conclusion

In general, yield results were variable. In 1998, glycine betaine treated plants had numerically greater boll numbers, boll weights and lint yields, but differences were not significant (P=0.05)(Meek and Oosterhuis, 1999). In 1999, yields were inconsistent, with glycine betaine generally having no positive effect. No differences in photosynthetic rate between treated and untreated plant were encountered either year. In 1999, trends in cellular water relationships suggested that glycine betaine might assist in osmotic adjustment but this did not enhance yields.

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Table 1. Effects of foliar application of glycine betaine on boll weight and lint yield of dryland cotton in 1999 at Clarkedale, Arkansas.

Treatment	Boll Weight g/boll	Lint Yield g/m^2
Control	4.1	916
2 kg/ha weekly	4.9	825
4 kg/ha weekly	4.4	841
6 kg/ha weekly	4.7	829
2 kg/ha biweekly	4.7	931
4 kg/ha biweekly	4.7	857
6 kg/ha biweekly	4.6	801
2 kg/ha monthly	4.6	864
4 kg/ha monthly	4.6	842
6 kg/ha monthly	4.7	827
LSD (0.05)	0.39	75.6

Table 2. Effects of glycine betaine, water stress and cultivar on boll weight and lint yield in 1999 at Clarkedale, Arkansas. No differences between glycine betaine treated and untreated plants were significant.

Treatment			Boll Weight g/boll	Lint Yield g/m^2
Siokra L-23				
	Water-Stressed			
		Control	3.6	760
		Glycine Betaine	3.4	671
	Well-Watered			
		Control	3.8	811
		Glycine Betaine	3.7	777
Stoneville 506				
	Water-Stressed			
		Control	3.3	823
		Glycine Betaine	3.5	887
	Well-Watered			
		Control	3.8	1031
		Glycine Betaine	3.9	1242

Table 3. Effects of water stress and cultivar on photosynthesis and osmotic potential in 1999 at Clarkedale, Arkansas. No differences were significant.

Treatment			Photosynthesis µmol/CO_2/sec	Osmotic Potential MPa
Siokra L-23				
	Water-Stressed			
		Control	36.4	-1.84
		Glycine Betaine	36.4	-1.92
	Well-Watered			
		Control	38.1	-1.76
		Glycine Betaine	37.0	-1.78
Stoneville 506				
	Water-Stressed	Control	34.1	-2.21
		Glycine Betaine	34.1	-2.35
	Well-Watered			
		Control	38.9	-1.49
		Glycine Betaine	34.0	-1.89