DROUGHT TOLERANCE AND FOLIAR SPRAYS OF GLYCINE BETAINE

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Abstract

Water is the most liming factor in cotton production, and numerous efforts have been made to improve crop drought tolerance. Glycine betaine was applied to field-grown cotton at two rates with and without adjuvants. Some plants received applications at first flower + one and two weeks, while others were treated at first flower + one,two, three, and four weeks. Treated plants had significantly higher midseason boll numbers, stomatal resistance rates, number of effective sympodia, and boll retention in the second fruiting position. No significant differences were observed between treatments in yield measurements at time of harvest. Trends suggested glycine betaine has the potential to increase yield in cotton subjected to mild water-deficit stress, however more research needs to be conducted regarding optimal rate and timing of applications.

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 osmotic adjustments to cells 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 (Agboma et al., 1997; Makela et al., 1997, Rhodes and Hanson, 1993).

Glycine betaine has been exogenously applied to many nonaccumulating and accumulating crops in an effort to improve stress tolerance and yield. Previous studies have addressed many questions related to the action of glycine betaine, including the effects of glycine betaine on plants during periods of adequate water supply. Some of the crops include maize and sorghum (Agboma et al., 1997), and cotton (Gorham, 1998). Results have varied, and appear to depend on numerous factors such as type of crop, and timing and rate of application, and environmental conditions. More research needs to be conducted to identify the effects of exogenous application of glycine betaine on the physiological activity and yield of crop plants, including cotton.

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The objectives of the 1998 field study were: (1) to determine the effects of different application rates of glycine betaine in field-grown cotton, (2) to determine the effects of an adjuvant on the response to foliar-applied glycine betaine on field-grown cotton (*Gossypium hirsutum* L.) subjected to water deficit stress after first flower and (3) to determine the effects of multiple applications of glycine betaine on field-grown cotton.

Materials and Methods

The field study was conducted at the Arkansas Agricultural Research and Extension Center, Fayetteville, Arkansas. The cotton (*Gossypium hirsutum* L.) cultivar, Sure-Grow 125, was planted into a Captina silt loam soil, on May 15, 1998. The plot size was two rows with 40 inch row spacing and five-meter length. Irrigation was applied equally to all treatments, when needed according to Arkansas Cooperative Extension recommendation. A watering was withheld two weeks after first-flower in an effort to impose mild water-deficit stress. The experiment consisted of eight treatments in a randomized complete block design with four replications. Glycine betaine was supplied in the form of the commercial product GREENSTIM® (Finnsugar Bioproducts, Helsinki, Finland). Adjuvants were non-ionic in composition. Treatments are listed below:

1. Control - sprayed with water only.[1]
2. GREENSTIM applied at 3 kg/ha.[1]
3. GREENSTIM applied at 6 kg/ha.[1]
4. GREENSTIM applied at 3 kg/ha - 0.2% v/v DYNE-AMIC®.[1]
5. GREENSTIM applied at 6 kg/ha - 0.2 % v/v DYNE-AMIC®.[1]
6. GREENSTIM applied at 3 kg/ha - 0.5 % v/v MONSOON®.[1]
7. GREENSTIM applied at 6 kg/ha - 0.5% v/v MONSOON®.[1]
8. GREENSTIM applied at 3 kg/ha - 0.5% v/v MONSOON®.[2]

[1]Foliar applications made at one and two weeks after first-flower.
[2]Foliar applications made at one, two, three, and four weeks after first-flower.

Foliar applications were made in the early morning using a CO_2 backpack sprayer calibrated to deliver a volume of 200 L/ha (20 gal/acre) with a three nozzle assembly directed at the terminal and into the middle of the canopy.

Photosynthetic rates and stomatal resistances were measured within two hours of solar noon using a LICOR-6200 portable photosynthesis system. These measurements were taken at four, five, and six weeks after first-flower in treatments one, two, six, and eight. Mid-season boll numbers were recorded for all treatments four weeks after first-flower. Final plant maps were established according to the COTton MAPping (COTMAP) program (Bourland and Watson, 1990) to determine specific growth differences between treatments. Yield determination was accomplished by hand harvesting two one-meter rows from each plot.

Results and Discussion

Yield Components

Mid-season boll number (Table1) was significantly higher in treatment three (two applications of GREENSTIM at 6 kg/ha with no adjuvant) when compared to untreated plants. No significant differences (p=0.05) were observed in yield measurements at time of harvest, however control plants had the lowest seed cotton yields. Treatment eight (four applications of GREENSTIM at 3 kg/ha of MONSOON) had the lowest number of final bolls, yet highest boll weights.

Photosynthetic Parameters

No significant differences in photosynthetic rate (Table 2) were detected between treatments. Stomatal resistance was significantly higher at four weeks after first flower in treatment eight (four applications of GREENSTIM at 3 kg/ha with MONSOON) when compared to control plants.

Plant Mapping

Results from COTMAP are illustrated in Table 3. Significant differences were observed in number of effective sympodia and boll retention in the second fruiting position. In both of these measurements, treatment eight (four applications of GREENSTIM at 3 kg/ha with MONSOON) was significantly higher than control plants. Although not significant, control plants had a higher percentage of total bolls on monopodial branches.

Literature Cited

Agboma, M., M.G.K. Jones, P. Peltonen-Sainio, H. Rita, and E. Pehu 1997a. Exogenous glycinebetaine enhances grain yield of maize, sorghum and wheat grown under two supplementary watering regimes. J. Agron. & Crop Sci. 178:29-37.

Bourland, F.M., and C.E. Watson, Jr. 1990. COTMAP, a technique for evaluating structure and yield of cotton plants. Crop Sci. 30:224-226.

Gorham, J., K. Jokinen. 1998. Glycinebetaine treatment improves cotton yields in field trials in Pakistan. p. 329. World Cotton Conference II, Athens, Greece. *In press.*

Hendrix, D. A., W. S. Pierce. 1983. Osmoregulation and membrane-mediated responses to altered water potential in plant cells. Cryobiology. 20:466-486.

Makela, P., P. Peltonen-Sainio, P. Jokenin, E. Pehu, H Setala, R. Hinkkanen, S. Somersalo 1996a. Uptake and translocation of foliar applied glycine betaine in crop plants. Plant Sci. 121: 221-230.

Morgan, J. 1984. Osmoregulation and water stress in higher plants. Ann. Rev. Plant Physiol. 35:299-319.

Table 1. Effects of foliar application of glycinebetaine on yield and yield components of field-grown cotton in 1998 at Fayetteville, Arkansas. Mid-season boll number was measured 4 days after third foliar application. Seed cotton yield, final boll number, and boll weight was measured at time of harvest.

Treatment	Mid-season boll number	Final boll number	Boll weight	Seedcotton yield
	no./m^2	no./m^2	g/boll	g/m^2
Control[1] water only	40.0	34.5	4.99	400.3
GREENSTIM[1] 3 kg/ha no adjuvant	53.8	35.0	4.99	430.3
GREENSTIM[1] 6 kg/ha no adjuvant	57.8	37.1	4.99	457.3
GREENSTIM[1] 3 kg/ha DYNE-AMIC	49.3	38.0	4.70	441.8
GREENSTIM[1] 6 kg/ha DYNE-AMIC	51.3	35.4	4.97	433.7
GREENSTIM[1] 3 kg/ha MONSOON	44.5	38.0	4.86	456.0
GREENSTIM[1] 6 kg/ha MONSOON	53.0	35.1	4.90	423.2
GREENSTIM[2] 3 kg/ha MONSOON	55.3	33.0	5.33	437.4
LSD (0.05)	15.4	6.6	0.34	86.5

[1] Foliar applications made at one and two weeks after first flower.
[2] Foliar applications made at one, two, three, and four weeks after first flower.

Table 2. Photosynthesis, and stomatal resistance rates of field-grown cotton receiving foliar applications of glycine betaine in 1998 at Fayetteville, Arkansas. Measurements were taken with Licor 6200 at four, five, and six weeks after first flower (FF+4, FF+5, and FF+6, respectively).

Treatment	Photosynthesis (μmol CO_2/m^2/s)			Stomatal Resistance (mol/m^2/s)		
	FF+4	FF+5	FF+6	FF+4	FF+5	FF+6
Control[1] water only	33.4	36.3	22.6	0.132	0.120	0.801
GREENSTIM[1] 3 kg/ha no adjuvant	33.0	25.8	20.6	0.190	0.217	0.677
GREENSTIM[1] 6 kg/ha MONSOON	33.6	26.0	17.9	0.162	0.147	0.804
GREENSTIM[2] 3 kg/ha MONSOON	30.8	33.3	19.4	0.249	0.194	1.002
LSD (0.05)	10.1	22.5	13.0	0.102	0.007	0.576

[1] Foliar applications made at one and two weeks after first flower.
[2] Foliar applications made at one, two, three, and four weeks after first flower.

Table 3. Results of COTton MAPping Analysis Program obtained at harvest.

Treatment	No. effective sympodia	Boll retention 2nd position	% total bolls on monopodia
Control[1] water only	6.53	14.25	31.88
GREENSTIM[1] 6 kg/ha no adjuvant	7.58	18.00	32.28
GREENSTIM[1] 6 kg/ha MONSOON	8.35	18.38	25.28
GREENSTIM[2] 3 kg/ha MONSOON	9.25	18.78	27.18
LSD (0.05)	1.97	3.65	0.55

[1] Foliar applications made at one and two weeks after first flower.

[2] Foliar applications made at one, two, three, and four weeks after first flower.