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EFFICACY OF FOLIAR APPLICATIONS OF TRIMAX™ INSECTICIDE DURING WATER-DEFICIT STRESS ON THE PHYSIOLOGY AND YIELD OF COTTON

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Abstract

TRIMAX™ is a new insecticide from Bayer CropScience registered specifically for use in cotton. Research has shown that multiple application spray programs of Trimax, beginning early to mid-season, have resulted in enhanced yields, pest management and plant metabolism/health benefits. However, information is lacking on how Trimax effects plant growth and thereby enhances yield. It is hypothesized that the reported growth and yield advantage imposed by Trimax may be due, in part, to improved plant physiology, particularly under environmental stresses. To test this hypothesis, field studies were conducted in 2002 and 2003 at two test sites in Arkansas. Results from these studies have confirmed yield increases from multiple applications of Trimax. Furthermore, it appears that Trimax improves plant physiology, particularly during water stress, by activating enzyme defense systems, improving translocation and energy acquisition and maintaining cell integrity. The overall result is that the plant experiences less environmental stress, and growth and yields are enhanced.

Introduction

Trimax is a new insecticide from Bayer CropScience registered specifically for use on cotton. It is an Imidacloprid product discovered by Bayer in 1985 and was the first commercially introduced insecticide in the class of chloronicotinyl insecticides. Trimax provides excellent control of the major sucking/piercing insects in cotton (aphids, cotton fleahopper, banded winged whitefly, plant bugs, excluding *Lygus hesperus*, green stinkbug and southern stinkbug). It also has ovicidal effects on bollworms and budworms. In addition, Trimax has a strong antifeeding effect providing excellent protection from damaging pests feeding on cotton. Trimax can be applied up to five times per growing season, allowing multiple applications in sustained pressure and multiple pest situations. The active ingredient in Trimax is imidacloprid, the only insecticide in the nitroguanidine subclass of chloronicotinyl insecticides with a chloropyridine side chain. This distinguishing side chain is structurally related to compounds like nicotinamide and chloronicotinic acid known as systemic plant resistance inducers. These substances help plants to better tolerate environmental stress during drought, disease and insect attacks.

Enhanced Growth and Yields From TRIMAX

Pest management and plant metabolism/health benefits of Trimax, especially when used in multiple application spray programs beginning early to mid-season, have resulted in enhanced yields (ref: Bayer CropScience Technical Bulletin TRO211, 2002). Significant yield enhancement benefits have been observed even in situations without economic target insect infestations. However, information is lacking on how Trimax affects plant growth and thereby enhances yield. Therefore, the current study was designed to understand plant response to foliar application of Trimax during water-deficit stress with particular emphasis on the physiological and biochemical changes that occur, and how these changes may effect the development of yield. In order to understand the biochemical changes induced by Trimax on cotton, it is also proposed to determine the activity of antioxidant enzymes after foliar application on cotton leaves. It is hypothesized that the reported growth and yield advantage imposed by Trimax may be due, in part, to improved plant physiology and the activation of antioxidant enzymes to detoxify the plant of free radicals which are always present due to the numerous environmental stresses that crops face daily. Glutathione is one such enzyme involved in a wide range of metabolic processes (Meister and Anderson, 1983) and its content increases considerable under stressful conditions (Smith et al., 1990). The overall objective of these studies is to study the effect of the insecticide Trimax on the growth, physiology, biochemistry and yield of cotton under water-stressed conditions as opposed to a well-watered environment.

Materials and Methods

The effect of Trimax applications during water-deficit stress was studied at two locations in Arkansas in 2003. At the Clarkedale location, in northeast Arkansas, Trimax was evaluated for its potential to increase cotton lint yields and quality under well-watered and water-stressed conditions. At Fayetteville, in northwest Arkansas, Trimax was evaluated to see what effect Trimax applications during a water-stress had on the physiology, biochemistry and yield of cotton. The study was designed as a randomized, split-plot design with six replications at both test locations. The water deficit conditions were imposed using an irrigation system specifically designed to impose well-watered and water-deficit conditions differentially to a randomized field plot system.

Treatments at both locations consisted of (1) an untreated control, and (2) Trimax @ 1.5 oz/acre subjected to well-watered and water-stressed conditions. Cotton (*Gossypium hirsutum L.*) cultivar ST 474 was planted on May 30 at Clarkedale and

May 23 in Fayetteville in 2003. Trimax was applied with a CO_2 backpack sprayer at three weekly intervals starting at pinhead square at Clarkedale. However, at Fayetteville Trimax was applied at weekly intervals starting at two weeks after first flower (FF2).

Physiological measurements were taken at the Fayetteville location at three weeks after first flower (FF3) and included canopy temperature, leaf chlorophyll content measured with a Minolta SPAD meter, specific leaf weight, leaf Adenosine triphosphate (ATP), leaf soluble protein, leaf membrane leakage, and select antioxidant enzymes. At harvest, lint yield, components of yields and fiber quality were evaluated at both Clarkedale and Fayetteville locations. Yield component data included average boll weight, bolls per acre, seeds per acre, seeds per boll, seed weight, fiber per seed and gin turnout. Node above white flower (NAWF) counts were also evaluated at Clarkedale in order to determine if Trimax provided earlier maturity of the cotton crop.

With the exception of leaf protein and enzymes, physiological measurements at FF3 occurred 2-3 days after the first Trimax application (which occurred during a moderate water-stress). For protein and enzyme analysis, leaf samples were collected 2 days following Trimax application based on enzyme sequential harvest data in 2003, which indicated a decline in enzyme activity three days past Trimax applications.

Results and Discussion

Yield and Yield Components

Trimax significantly increased lint yields under both well-watered and water-deficit stress conditions at Clarkedale and under well-watered conditions at Fayetteville in 2003 (Figure 1). At Clarkedale, the increase in lint yield observed by Trimax was greater under water-deficit conditions as opposed to well-watered conditions (Figure 1). Boll and yield component data from Clarkedale (Table 1) and Fayetteville (Table 2) indicate that the increase in lint yield from Trimax applications was the result of more bolls and seeds per acre, and less on fiber per seed and boll weight. Gin turnout was numerically increased from Trimax applications (Figure 2) with the greatest numerical increase being under water-deficit conditions (compensation between fiber and seed).

Fiber Quality

Fiber quality was very similar between Trimax treated and untreated plots (Table 3). At the water level, fiber length, uniformity and elongation were numerically increased under well-watered conditions and fiber strength and micronaire were numerically increased under water-deficit conditions.

NAWF

NAWF values, taken at Clarkedale at FF2, were not significantly different between Trimax treated and untreated plots. However, there was a numerical decrease in NAWF for Trimax treated plots under water-deficit conditions, but not under well-watered conditions (Figure 3). Trimax did not show the same significant increase in earliness that was observed in 2002. At the water level, NAWF counts were significantly lower for water-stressed plants compared to well-watered plants (Figure 3).

Canopy Temperature

Canopy temperature was significantly higher under water-deficit conditions compared to well-watered conditions (Figure 4). The increase in plant canopy temperature of the water-stressed plants helps to show the stressful conditions that existed in the field at the time of Trimax applications. However, there were no significant differences between Trimax treated and untreated plants for cooling the cotton plant. The lack of effect on canopy temperature following Trimax application was to be expected since Trimax was not expected to effect water relations.

Leaf Chlorophyll and Specific Leaf Weight

There were no significant differences between Trimax-treated and untreated plants for measured leaf chlorophyll or specific leaf weight (Figure 5). However, Trimax treated leaves did appear to be thinner (lower specific leaf weight) indicated slightly less stress and contained less chlorophyll. The lower chlorophyll value was expected since the leaf was thinner. The untreated plants had thicker leaves (higher specific leaf weight) which would give a higher chlorophyll reading due to the chlorophyll being stacked in the leaf. To accurately determine chlorophyll between Trimax treated and untreated leaves, an extraction of the leaves should be done to determine actual chlorophyll concentration. Also, leaf chlorophyll was significantly higher under water-deficit conditions averaged over Trimax treatments (Figure 5).

Leaf ATP and Total Soluble Protein

Leaf ATP concentrations were significantly lower for Trimax treated plants under both water levels while protein concentrations were numerically higher for Trimax treated plants (Figure 6). The significant decrease in leaf ATP for Trimax treated plots could be expected since it cost the plant a lot of energy to make proteins, and Trimax treated plots had higher leaf protein concentrations. Also, under a mild stress the Trimax plots were more efficient at translocating energy sources out of the leaf.

Leaf Membrane Leakage and Leaf Wax

Trimax treated plants had numerically lower leaf membrane leakage values under water-deficit conditions as opposed to well-watered conditions (Figure 7). There were no differences or trends in regards to leaf wax concentrations following Trimax applications. At the water level, leaf wax was numerically increased and membrane leakage was significantly increased under water-deficit conditions (Figure 7). As was the case with canopy temperature, these measurements help to show the considerable stress the plants were exhibiting at the time of Trimax applications.

Antioxidant Enzymes

Antioxidant enzyme activity is the one area of research that needs further investigation and more research results in order to properly explain what is occurring in terms of enzyme activation during an environmental stress event or following Trimax applications. This will allow us to determine (a) the time sequence at which each enzyme is being activated relative to the stress and (b) how the activity of one enzyme reacts to the activity of another enzyme. It is believed that when one enzyme is activated another enzyme may be silenced. Enzyme results from FF3 during 2003 indicated that Trimax applications significantly increased catalase activity under water-deficit conditions (Table 4). Furthermore, all enzymes showed activity responses under water-deficit conditions as a result of Trimax application.

References

Meister, A. and Anderson, M.E. 1983. Glutathione. Annu. Rev. Biochem. 52:711-760.

Smith, I.K., Polle, A. and Rennenberg, H. 1990. Glutathione. *In*: Alcher, R.G. mechanisms. pp. 201-215. Wiley-Liss, New York.

Table 1. Boll and yield components of TRIMAX treated and untreated plots under well-watered and water-deficit conditions at Clarkedale, AR in 2003.

Treatment	Boll Weight	Bolls/A	Seeds/A	Fiber/Seed	Seed Weight	Seeds/Boll
	g/boll	#/A	#/A	mg	g/100 seed	#/boll
TRIMAX--Water	4.34	111,000[x]	3,127,000[x]	65.3	9.42	28.0
Control--Water	4.23	90,000	2,478,000	64.0	9.31	27.7
TRIMAX--Dryland	4.33	156,000[x]	4,264,000[x]	70.4	9.25	27.3
Control-Dryland	4.30	105,000	2,917,000	67.2	9.21	27.6

[x] Significant at $p \leq 0.05$ for the paired treatments.

Table 2. Boll and yield components of TRIMAX treated and untreated plots under well-watered and water-deficit conditions at Fayetteville, AR in 2003

Treatment	Boll Weight	Bolls/A	Seeds/A	Fiber/Seed	Seed Weight	Seeds/Boll
	g/boll	#/A	#/A	mg	g/100 seed	#/boll
TRIMAX--Water	3.50	374,000[x]	9,827,000[x]	53.5	8.10	26.2
Control--Water	3.41	322,000	8,303,000	52.0	8.07	26.2
TRIMAX--Dryland	3.88[x]	267,000	7,016,000	65.0	8.86	25.8
Control-Dryland	3.47	282,000	7,012,000	57.6	8.29	25.0

[x] Significant at $p \leq 0.05$ for the paired treatments.

Table 3. Fiber quality components of TRIMAX treated versus untreated plots under well-watered and water-deficit conditions at Clarkedale, AR in 2003

	Fiber Quality				
Treatment	Length	Uniformity	Elongation	Strength	Micronaire
	inches	%	inches	g/tex	unitless
TRIMAX--Water	1.14	84.3	9.25	29.3	4.04
Control--Water	1.15	84.3	9.25	29.3	4.00
TRIMAX--Dryland	1.11	83.4	9.13	30.0	4.30
Control--Dryland	1.13	84.8	9.08	29.7	4.28

Non-significant at $p \leq 0.05$ for the paired treatments.

Table 4. Leaf antioxidant enzyme concentrations of TRIMAX treated and untreated plots under well-watered and water-deficit conditions measured FF3 at Fayetteville, AR in 2003.

	Antioxidant Enzymes			
Treatment	Catalase	Peroxidase	Ascorbate	Glutathione
	mM/g fresh wt	mM/g fresh wt	mM/g fresh wt	nM/ g fresh wt
TRIMAX--Water	1068	3.20	0.016	353
Control--Water	1059	3.19	0.015	361
TRIMAX--Dryland	1083[x]	2.32	0.013	343
Control--Dryland	764	2.20	0.017	199

[x] Significant at $p \leq 0.05$ for the paired treatments.

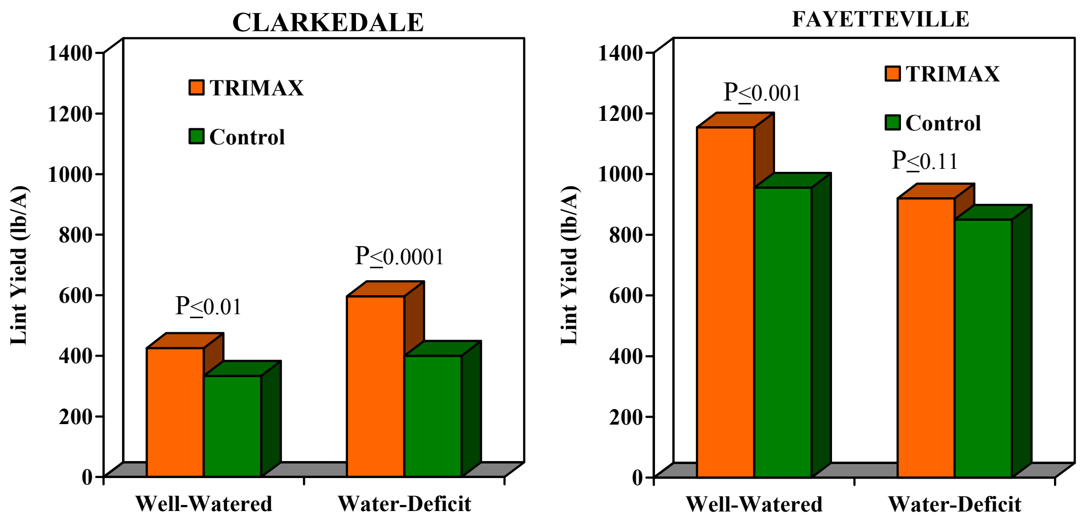

Figure 1. Effect of foliar TRIMAX applications under well-watered and water-deficit conditions on lint yields at Clarkedale and Fayetteville, AR in 2003.

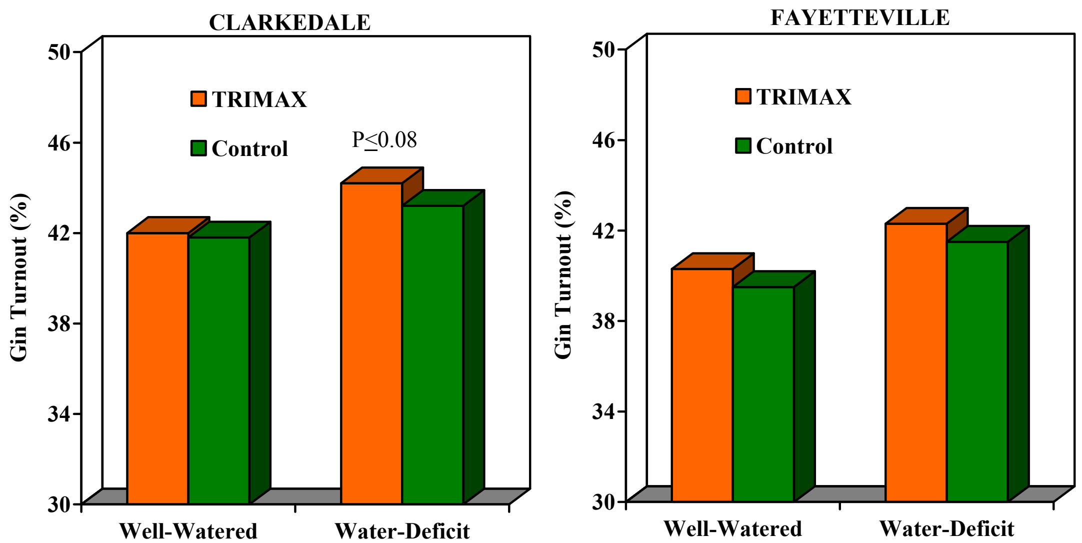

Figure 2. Gin turnout of TRIMAX treated and untreated plots under well-watered and water-deficit conditions at Clarkedale and Fayetteville, AR locations in 2003.

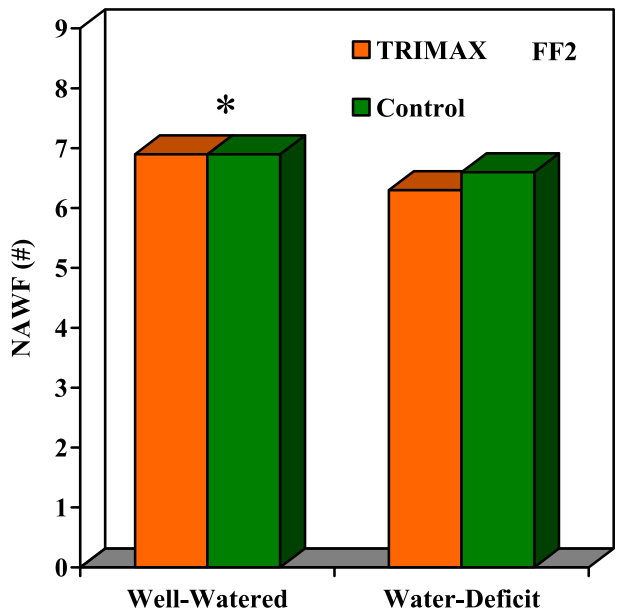

Figure 3. NAWF (maturity) of TRIMAX treated and untreated plots under well-watered and water-deficit conditions at Clarkedale, AR in 2003. *Indicates a significant p≤0.05 difference at the water level averaged over TRIMAX treatments.

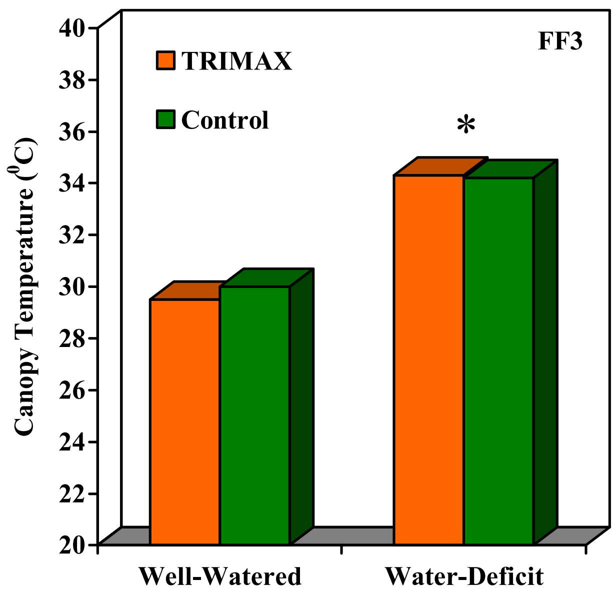

Figure 4. Canopy temperature of TRIMAX treated and untreated plots under well-watered and water-deficit conditions at Fayetteville, AR in 2003. *Indicates a significant p≤0.05 difference at the water level averaged over TRIMAX treatments.

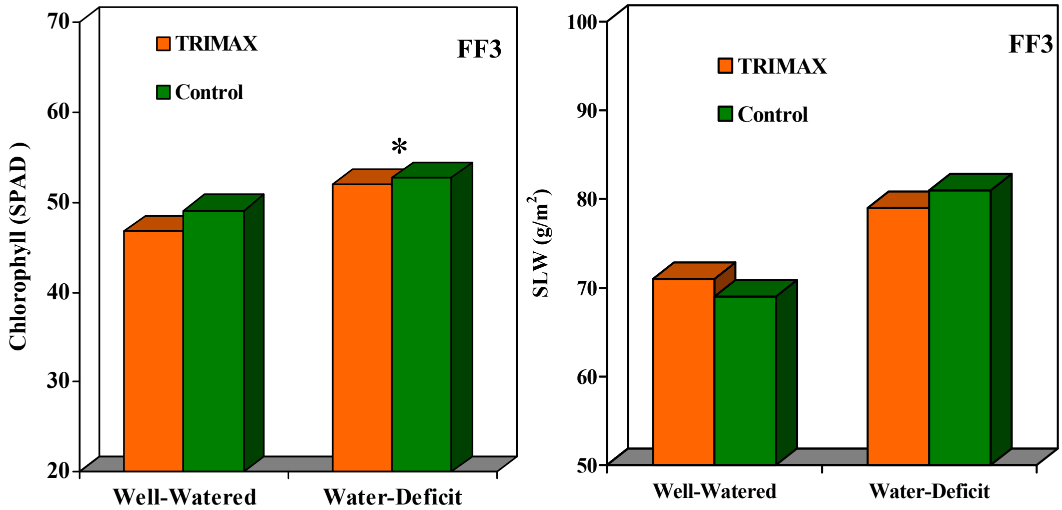

Figure 5. Leaf chlorophyll and specific leaf weight (SLW) of TRIMAX treated and untreated plots under well-watered and water-deficit conditions at Fayetteville, AR in 2003. *Indicates a significant ($p \leq 0.05$) difference at the water level averaged over TRIMAX treatments.

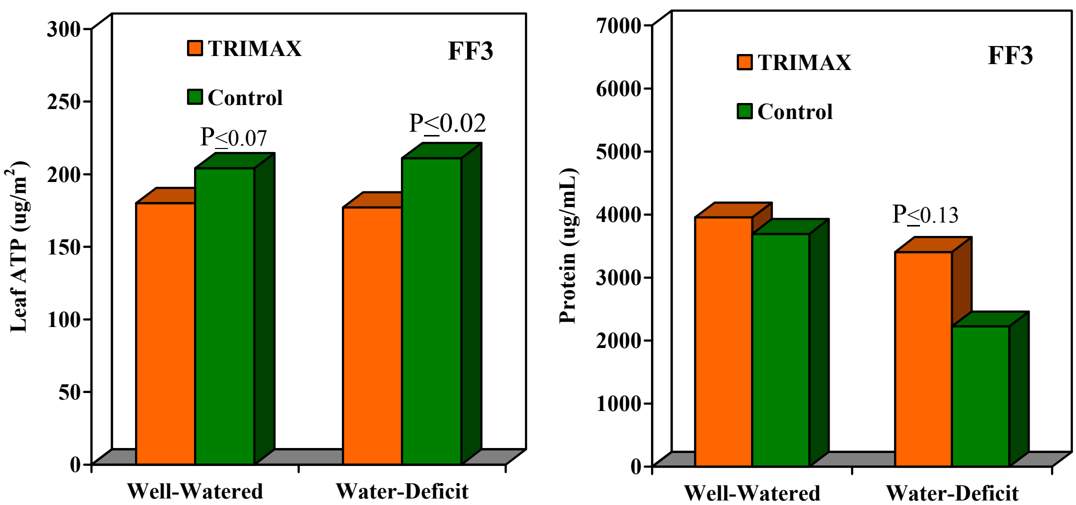

Figure 6. Leaf ATP and leaf total soluble protein of TRIMAX treated and untreated plots under well-watered and water-deficit conditions at Fayetteville, AR in 2003.

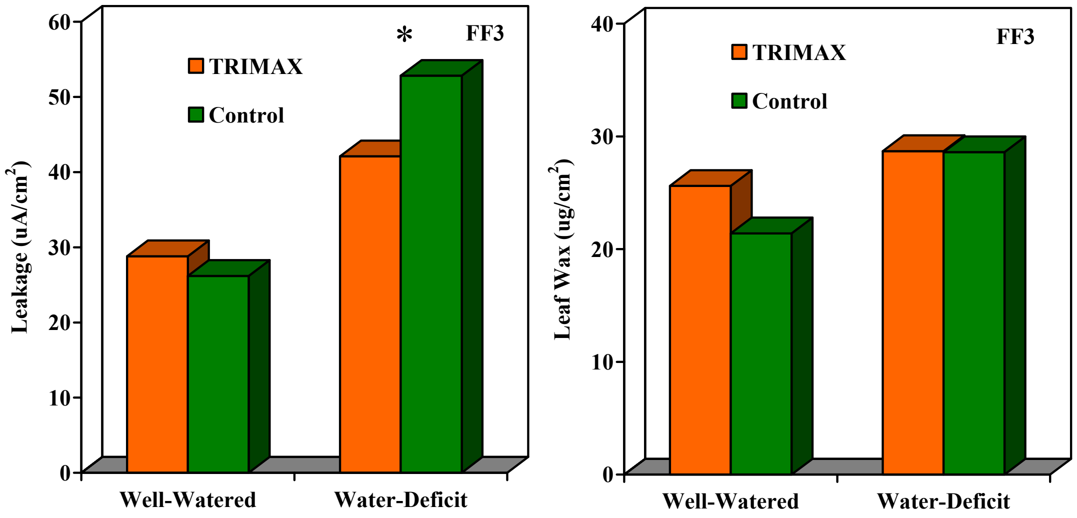

Figure 7. Leaf membrane leakage and leaf wax concentration of TRIMAX treated and untreated plots under well-watered and water-deficit conditions at Fayetteville, AR in 2003. *Indicates a significant $p \leq 0.08$ difference at the water level averaged over TRIMAX treatments.