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# EFFECTS OF TRIMAX™ ON THE PHYSIOLOGY, GROWTH AND YIELD OF COTTON

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## Abstract

TRIMAX™ is a new insecticide from Bayer CropScience specifically for use on cotton that provides excellent control of major sucking/piercing insects in cotton. In addition, 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. The current study was designed to understand plant response to foliar application of TRIMAX™ with particular emphasis on the physiological and biochemical changes that occur and how these may effect the development of yield. Three sets of experiments were designed to supply information to quantify plant growth response to TRIMAX™. The information should also permit us to determine, or at least formulate, an explanation of how TRIMAX™ is affecting the growth and development of the cotton plant, and therefore enhancing yield.

## Introduction

TRlMAX™ 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. TRlMAX™ 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, TRlMAX™ has a strong antifeeding effect providing excellent protection from damaging pests feeding on cotton. TRlMAX™ can be applied up to five times per growing season, allowing multiple applications in sustained pressure and multiple pest situations. The active ingredient in TRlMAX™ 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 nicotinamde 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 TRlMAX™, 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™ with particular emphasis on the physiological and biochemical changes that occur and how these may effect the development of yield.

In order to understand the biochemical changes induced by TRIMAX™ on cotton, it is also intended to determine the activity of antioxidant enzymes after foliar application on cotton leaves. Endogenously applied agrochemicals can induce biochemical and physiological changes in the host plants. Insects have also been shown to induce changes in the oxidative status of a variety of crops. It is hypothesized that the apparent growth advantage imposed by TRIMAX™ may be due, in part, to 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. The overall objective of these studies is to study the effect of the insecticide TRIMAX™ on the growth and physiology of cotton with some emphasis on antioxidant enzyme activity.

## Materials and Methods

Field studies were conducted at the University of Arkansas Delta Branch Experiment Station in Clarkedale, northeast Arkansas, and also at the Main Experiment Station in Fayetteville, northwest Arkansas. Additional studies will be conducted in controlled environment chambers at the Altheimer Laboratory in Fayetteville to further elucidate the mode of action of TRIMAX™. A randomized, split-plot design with six replications was used in Clarkedale, and a randomized complete block design with six replications was used in Fayetteville. At Clarkedale, the TRIMAX™ treatments were evaluated under both well-watered and water-deficit conditions accounting for the split-plot design. Water deficit was imposed using an irrigation system specially designed to impose well-watered and water-deficit conditions differentially to a randomized field plot system. In Fayetteville, foliar TRIMAX™ applications were evaluated only under well-watered conditions.

Treatments consisted of (1) an untreated control, and (2) TRIMAX™ @ 1.5 oz/acre. The cotton cultivar Suregrow 747 was planted on May 16, 2002 in Clarkedale, and on May 22, 2002 in Fayetteville, in a Captina silt loam. TRIMAX™ was applied with a $CO^2$ backpack sprayer at three weekly intervals after pinhead square at Clarkedale and once during peak squaring at Fayetteville.

At Clarkedale, measurements were made of (a) plant growth by classical growth analysis, plant mapping, and NAWF, (b) plant physiological response by measuring a range of physiological parameters including nonstructural carbohydrate concentrations, photosynthesis, canopy temperature, specific leaf weight (SLW) and chlorophyll content, (c) plants ability to tolerate stress by measuring antioxidant enzymes, and (d) final lint yield, yield components, and sequential harvest as a measure of yield earliness (sequential harvest data taken by Roger Bowman and Alan Hopkins from Bayer CropScience). Photosynthesis and canopy temperature were recorded using a LICOR 6200 portable photosynthesis system and a handheld infrared thermometer, respectively.

At Fayetteville, measurements were made of (a) final yield and yield components, (b) and enzyme activity from leaf material collected at 3 hour intervals for the first 24 hours and daily for one week beginning immediately following the foliar application of TRIMAX™ (data not shown).

## Results and Discussion

### Effects of TRIMAX™ on Plant Growth

Applications of TRIMAX™ during square development appeared to have a stimulatory effect on plant growth, although most of the parameters measured were not significantly different ($P \leq 0.05$) from the untreated control (Table 1). Table 1 shows that TRIMAX™ increased plant growth, i.e. as demonstrated by an increase in dry matter of plant components. These differences were visually obvious at first flower but not apparent during boll development and at harvest.

### Effects of TRIMAX on Plant Physiology

TRIMAX™ decreased specific leaf weight and increased chlorophyll content, but had no effect on photosynthesis or canopy temperature (Table 2). The lack of effect on canopy temperature is to be expected as the crop was not under any appreciable water deficit stress and TRIMAX™ was not expected to effect plant water relations. The increase in chlorophyll was difficult to explain. However, the decrease in specific leaf weight may be related to improved metabolism and translocation out of the leaf.

### Effects of TRIMAX™ on Carbohydrates and Antioxidant Enzymes

TRIMAX™ did not significantly affect carbohydrate concentrations (Table 3). However, there was a significant ($P \leq 0.05$) decrease in the level of the antioxidant enzyme glutathione reductase (Table 3). All living organisms produce reactive oxygen species (such as superoxide, hydrogen peroxide and hydroxyl radical) as part of normal metabolism particularly under stressful environments. To prevent excessive cellular oxidation from the production of these reactive oxygen metabolites, plants have evolved strategies such as an antioxidant defense system to detoxify the plant and remove these harmful oxygen radicals. It is hypothesized that the apparent growth advantage imposed by TRIMAX™ is in part due to the activation of these 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 involved in a wide range of metabolic processes (Meister and Anderson, 1983) and its content increases considerable under stressful conditions (Smith et al., 1990). A major function of glutathione is thought to be that of protection against oxidative biotic and abiotic stress, i.e. SO2, O3, UV irradiation, drought, extreme temperatures, and attack by other organisms. Our results show a significant increase in glutathione reductase in TRIMAX™ untreated plots which would support the hypothesis that the untreated plants are exhibiting stress whereas stress is alleviated for TRIMAX™ treated plants.

### Effects of TRIMAX™ on Lint Yields

Multiple foliar applications of TRIMAX™ numerically increased lint yield of field-grown cotton at Clarkedale in northeast Arkansas (Fig. 1A) and significantly increased ($P \leq 0.05$) lint yield at Fayetteville in northwest Arkansas where a single application of TRIMAX™ at 1.5 oz/A was sprayed (Fig. 1B). These increases in yield further support earlier reports of increased yields with multiple applications of TRIMAX™ used as an insecticide. Our subsequent measurements during the season were designed to investigate the effect that TRIMAX™ was having on plant growth (to cause the increased yield) and to elucidate possible physiological and biochemical explanations.

### Effects of TRIMAX™ on Earliness

TRIMAX-treated plants showed significant earliness as exhibited by a more rapid decline in nodes-above-white-flower (NAWF) (Fig. 2A). NAWF is a standard measure of earliness in the COTMAN crop monitoring program (Danforth and O'Leary, 1999), with a rapid decline to physiological maturity at NAWF=5 indicating earliness. In addition, a larger percentage of the total yield was harvested at the first pick (Fig. 2B). This indicated that a greater proportion of the total number of harvestable bolls matured earlier and were ready for picking before those of the untreated control plants. Early crop maturity is a very important attribute in cotton production for economic and pest control reasons. Also, early maturity is particularly important in the Mississippi Delta where the season length is already limited.

## Summary

In conclusion, TRIMAX™ insecticide was able to increase lint yields at both Arkansas test sites when foliar-applied at either single or multiple applications at the 1.5 oz/A rate. These increases in yield further support earlier reports of increased yields with multiple applications of TRIMAX™. Subsequent in-season measurements suggest that the increase in lint yield following foliar TRIMAX™ application is due in part to more efficient maintenance of physiological and biochemical processes by the cotton plant. However, more research needs to occur to fully validate the effectiveness of TRIMAX™ for increasing lint yields, quality and earliness and to better explain from a physiological and biochemical perspective how this yield enhancement is achieved.

## References

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

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Table 1. Effect of TRIMAX™ on plant growth and development measured three weeks after first flower. Clarkedale, Arkansas. 2002.

| | | Dry Weights | | | |
|---|---|---|---|---|---|
| Treatment | LAI ($m^2/m^2$) | Leaf ($g/m^2$) | Fruit ($g/m^2$) | Total ($g/m^2$) | Square # ($\#/m^2$) |
| Control | 2.9a[1] | 115a | 27.6a | 303a | 193a |
| TRIMAX | 3.3a | 132a | 36.6a | 356a | 187a |

[1]Numbers followed by the same letter are not significantly different (p•0.05).

Table 2. Effect of TRIMAX™ on physiological parameters measured three weeks after first flower. Clarkedale, Arkansas. 2002.

| Treatment | Specific Leaf Weight ($g/m^2$) | Chlorophyll (SPAD units) | Photosynthesis ($\mu mol/m^2/s$) | Canopy Temperature (C) |
|---|---|---|---|---|
| Control | 64.1 b[1] | 45.7 b | 23.3 a | 26.7 a |
| TRIMAX | 56.8 a | 51.7 a | 24.5 a | 26.6 a |

[1]Numbers followed by the same letter are not significantly different (p•0.05)

Table 3. Effect of TRIMAX™ on carbohydrate concentrations and antioxidant enzyme activity measured three weeks after first flower. Clarkedale, AR. 2002.

| Treatment | Glucose ($\mu g/cm^2$) | Sucrose ($\mu g/cm^2$) | Fructose ($\mu g/cm^2$) | Glutathione Reductase *mmol/min* |
|---|---|---|---|---|
| Control | 62.8a[1] | 133.6a | 86.4a | 202.85a |
| TRIMAX | 39.3a | 110.4a | 47.1a | 126.56b |

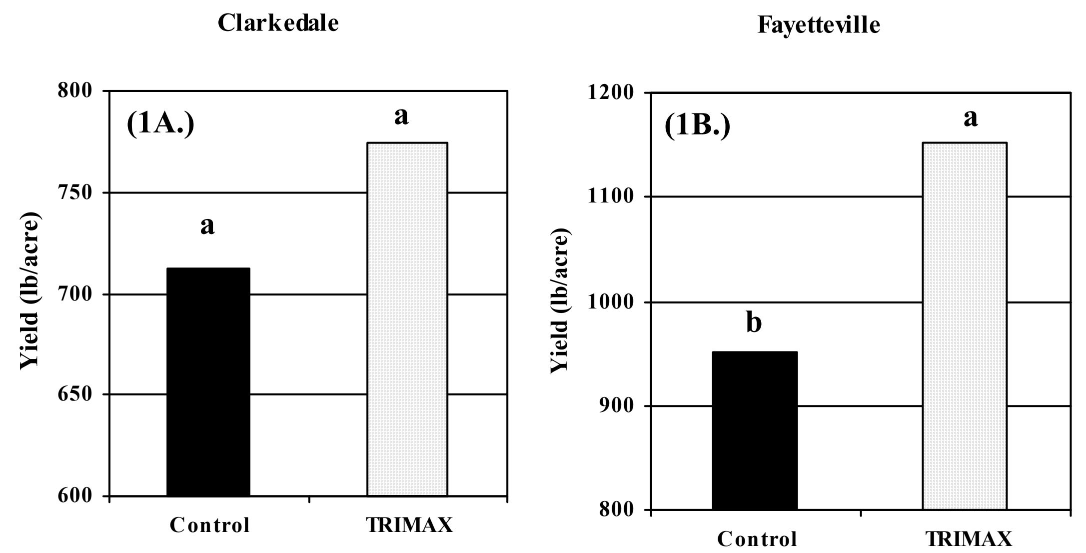


Figure 1. Effect of TRIMAX™ on Lint Yield in Arkansas in 2002. Columns superseded by a different letter are significantly different (P≤0.05).

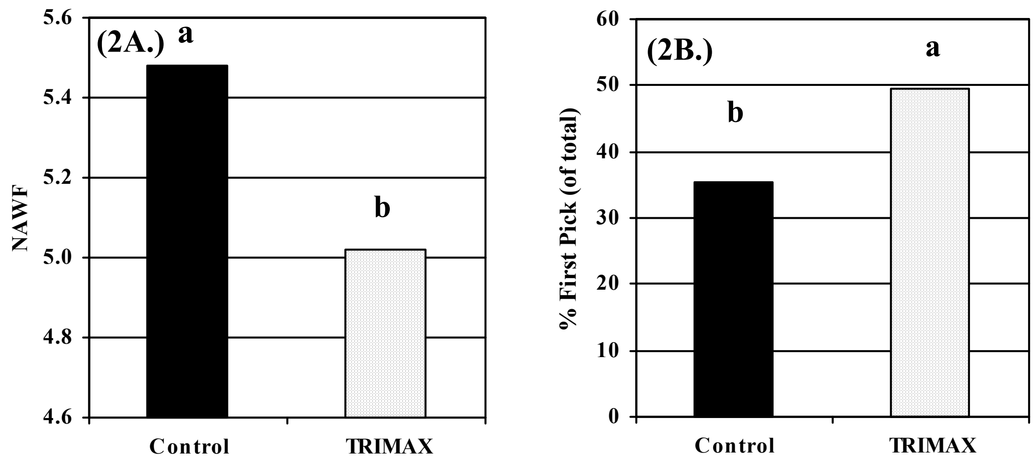


Figure 2. Effect of TRIMAX™ on earliness indicated by NAWF and percent first pick of total yield at Clarkedale, AR. Columns superseded by a different letter are significantly different (P≤0.05).