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Cotton Growth and Yield Enhancement by the Insecticide Trimax™

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ABSTRACT

Trimax™, a formulation of the active ingredient imidacloprid, is an insecticide registered for use in cotton (*Gossypium hirsutum* L.) to control the major sucking/piercing insects. There have been anecdotal reports of crop growth and yield enhancement after foliar applications of Trimax in the absence of insects, but no research has been conducted to support such reports. To study the effect of Trimax on the growth and yield of cotton, field trials were conducted for two years. Treatments consisted of an untreated control and Trimax at 109.5 mL/ha applied three times at weekly intervals starting at the pinhead square growth stage. Measurements were made of lint yield and yield components, fiber quality, as well as crop growth, dry matter partitioning and crop maturity. Increased lint yield due to applications of Trimax was recorded for both years of the study. Furthermore, increased dry matter production and number of fruit was observed after Trimax application indicating a positive effect on crop growth. The crop monitoring program COTMAN revealed an effect of Trimax on crop maturity, with the treated plants reaching the physiological maturity stage 3 to 5 days earlier than the untreated control. This is the first research documentation of the yield and growth promoting properties of Trimax in cotton in the absence of insects.

Keywords: dry matter partitioning, *Gossypium hirsutum*, imidacloprid, lint yield, maturity

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is subjected to a variety of biotic and abiotic stresses throughout its life cycle, and these play a key role in determining plant growth and yield. Insects have long been a major problem in cotton that decrease yields, but the development and use of synthetic insecticides have allowed for prevention of damage from insects (Ridgway 1984). Insecticides are widely used in cotton production although in many production areas the amount used has decreased with the advent of transgenic cultivars with the Bt (*Bacillus thuringiensis*) endotoxin.

Trimax™ (Bayer CropScience, Raleigh, NC) is a cotton specific formulation of imidacloprid (1-[(6-Chloro-3-pyridinyl)methyl]-*N*-nitro-2-imidazolidinimine), the first insecticide commercialized from the chloronicotinyl class of insecticides discovered in 1985 and introduced into the USA in 2000, prior to which it was marketed as Provado (Trimax Technical Bulletin, Bayer CropScience, Raleigh, NC). Imidacloprid was designed for control of the major sucking/ piercing insects in cotton. There have, however, also been anecdotal reports of imidacloprid causing yield increases in the absence of insect pests (e.g., Trimax Technical Bulletin, Bayer CropScience, Raleigh, NC).

Growth and yield improvements have been reported from the use of some insecticides. For example, White and Bourland (1986) suggested that enhanced cotton yields related to chlordimeform (trade names: Galecron, Fundal) was not all from insect control. Similarly, Bauer and Cothren (1990) reported that chlordimeform increased physiological activity, as measured by radish (*Raphanus sativus*) cotyledon expansion. Aldicarb (trade name: Temik) also has been reported to enhance growth, promote earliness and increase the number of bolls and squares on cotton plants grown at different temperatures (Reddy *et al*. 1990).

The imidacloprid molecule has a chloropyridine side chain that structurally resembles nicotinamide and nicotinic acid (niacin). These molecules have been shown to have antioxidant activity, for example inhibition of protein oxidation and reactive oxygen species-induced apoptosis, and scavenging of reactive oxygen species have been reported for nicotinamide *in vitro* (Kamat and Devasagayam 1999). In addition, Ogata *et al*. (2002) reported that many niacin-related compounds have scavenging activity against hydroxyl radicals.

Research in controlled conditions has revealed positive effects of Trimax on leaf photosynthesis and chlorophyll fluorescence yield of cotton plants (Gonias *et al*. 2008). In addition, these authors reported reduced activity of the antioxidant enzyme glutathione reductase, indicating that Trimax-treated plants were experiencing less of the detrimental effects of high temperature stress compared to untreated plants. The same authors described the beneficial effect of Trimax to be more prevalent under high temperature stress.

We hypothesized that foliar applications of Trimax will enhance growth and yield of cotton, due to improved plant metabolism. The current field study was designed to investigate the response of cotton to foliar applications of Trimax in the absence of insects, with particular emphasis on the growth, yield, and maturity of the crop.

MATERIALS AND METHODS

The effect of Trimax on the yield of the cotton was studied in field experiments in the summer of 2003 and 2004 at Clarkedale, Arkansas, on a Dundee silt loam soil (Typic Endoaqualf) using the cotton cultivar 'Stoneville 474'. The experimental plot was four rows wide by 15 m long. The fertilization program was determined according to preseason soil tests and recommended rates. Weed control was performed according to state recommendations and furrow irrigation was applied as needed for well-watered cotton. The study were maintained insect free by meticulous scouting and use of appropriate chemical products with active ingredients other than imidacloprid (such as acephate, dicrotophos), applied across all treatments.

The field experiments were planted on 13 May 2003 and 10

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Short Communication

May 2004, in a randomized complete block design with six replications. Treatments consisted of (1) an untreated control and (2) Trimax at 109.5 mL/ha (52.3 g ai/ha, recommended rate) applied weekly starting at the pinhead square stage for a total of three applications. Foliar treatments were applied with a CO_2 pressurized backpack sprayer calibrated to deliver 94 L/ha, early in the morning with no use of any surfactant.

The effect of Trimax on the growth of the cotton crop was evaluated for both years of the study using growth analysis to determine crop dry weight and leaf area. Plants from one meter of row from each plot were harvested three weeks after first flower growth stage (FF) from one of the middle two rows of each plot. In 2003, only the leaves were removed from the plants, while in 2004 the plants were separated into leaves, stems, and fruit. The leaf area of each sample was recorded with a LI-3100 Area Meter (LI-COR Inc., Lincoln, NE). Each plant component was placed in a paper bag and dried at 55°C for subsequent measurement of the dry weight and calculation of the dry weight partitioning (only in 2004) for each sample. Total dry weight and leaf area was estimated for both years of the study.

In addition, the SQUAREMAN subprogram of the crop monitoring program COTMAN (Danforth and O'Leary 1998) version 2 (University of Arkansas Division of Agriculture, Fayetteville, AR) was used to monitor the growth of the cotton crop. Data on the absence or presence of the first position squares from 10 plants per plot were collected weekly starting at the pinhead square (PHS) growth stage. Differences in crop maturity among the experimental plots were evaluated for all site years using the COTMAN program and its subprogram BOLLMAN. The number of nodes above the uppermost white flower of 10 plants per plot was recorded weekly starting at first flower until the nodes-above-white-flower-five stage (NAWF = 5).

Final yield was determined by mechanically harvesting the two middle rows of each plot once the bolls had fully matured. Yield components were recorded from 50 boll samples from each plot, collected before harvest, and included gin turnout, average boll weight, seed index, number of bolls and number seeds per unit area. Fiber quality was determined at the Cotton Fiber Testing Laboratory at the Louisiana State University Agronomy Department (Baton Rouge, LA) using 30 g sample from the hand-harvested bolls.

Statistical analysis was performed with the JMP 6 software (SAS Institute Inc., Cary, NC). Treatment effects and treatment × year interactions were tested with analysis of variance (ANOVA) at $\alpha \leq 0.05$. Means were separated with Student's *t*-test ($\alpha \leq 0.05$). When no significant treatment × year interaction was detected, data are presented as mean values estimated across years, except of dry matter partitioning where data were only available in 2004.

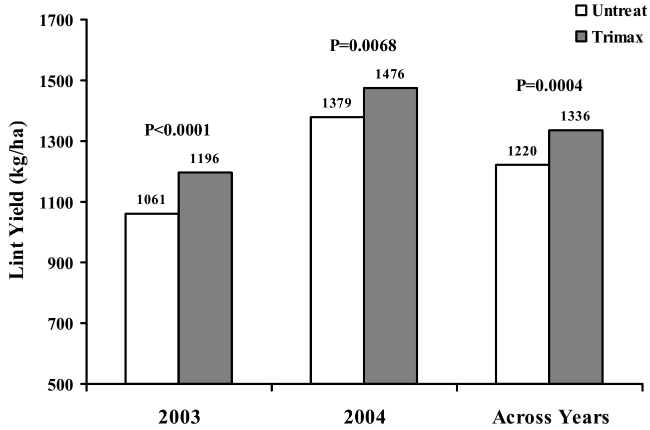

Fig. 1 Effect of Trimax on the lint yield of cotton. Probability values are given for each year and across years for treatment comparison.

RESULTS

Lint yield, components of yield and fiber quality

Foliar applications of Trimax had a significant positive effect on lint yield in both years of the study. Lint yield was increased by 135 kg/ha in 2003 and by 97 kg/ha in 2004 after application of Trimax compared to the untreated control (**Fig. 1**). No significant treatment × year interaction was detected (P=0.4482), with Trimax applications significantly increasing lint yield across years (**Fig. 1**).

Treatment × year interaction was not significant for any of the yield components and fiber quality properties recorded (**Tables 1** and **2**). Gin turnout, average boll weight and seed index were not affected by Trimax application (**Table 1**). However, the number of bolls per unit area and the number of seeds per unit area were significantly increased due to applications of Trimax (**Table 1**). Fiber quality properties did not differ significantly between the untreated control and the Trimax treatment (**Table 2**).

Crop growth and dry matter partitioning

At three weeks after flowering, applications of Trimax did not significantly affect number of main-stem nodes, leaf area and number of fruit per unit area (**Table 3**). However, plant height and total dry matter was significantly increased

Table 1 Yield components as affected by Trimax applications, averaged across the two years of the study.

Treatment	Gin Turnout %	Boll Weight g/boll	Seed Index g/100 seeds	Bolls #/m^2	Seeds Number/m^2
Untreated	43.8	4.55	8.50	61.9	1930.8
Trimax	43.6	4.60	8.64	66.9	2030.1
P-value	0.6551	0.4102	0.2850	0.0032	0.0322
Treatment × Year	0.8575	0.9059	0.3456	0.4593	0.2475

Table 2 Fiber quality properties as affected by Trimax applications, averaged across the two years of the study.

Treatment	Length mm	Strength g/tex	Uniformity %	Elongation %	Short Fiber Index %	Micronaire –
Untreated	27.18	26.12	83.13	9.34	6.73	3.99
Trimax	27.28	26.69	83.10	9.37	6.78	4.14
P-value	0.5094	0.2094	0.9354	0.8796	0.8911	0.1889
Treatment × Year	0.6356	0.2936	0.7463	0.7624	0.6824	0.1564

Table 3 The effect of Trimax on crop growth three weeks after first flower, averaged across the two years of the study.

Treatment	Height cm	Nodes #	Leaf Area m^2/m^2	Dry Weight g/m^2	Fruits [1] Number/m^2
Untreated	91.58	17.64	2.119	518.35	192
Trimax	95.08	17.70	2.236	617.08	190
P-value	0.0236	0.8092	0.9425	0.0021	0.9091
Treatment × Year	0.8193	0.5049	0.5363	0.9834	0.8196

[1] Total number of fruiting points including squares, flowers, and bolls.

Table 4 The effect of Trimax on dry matter and dry matter partitioning three weeks after first flower in 2004.

Treatment	Leaves		Stems		Fruit	
	g/m^2	%	g/m^2	%	g/m^2	%
Untreated	140.53	26.3	214.65	39.9	181.75	33.8
Trimax	165.71	26.0	229.48	36.3	239.96	37.7
P-value	0.0929	0.7196	0.3619	0.0296	0.0093	0.0349

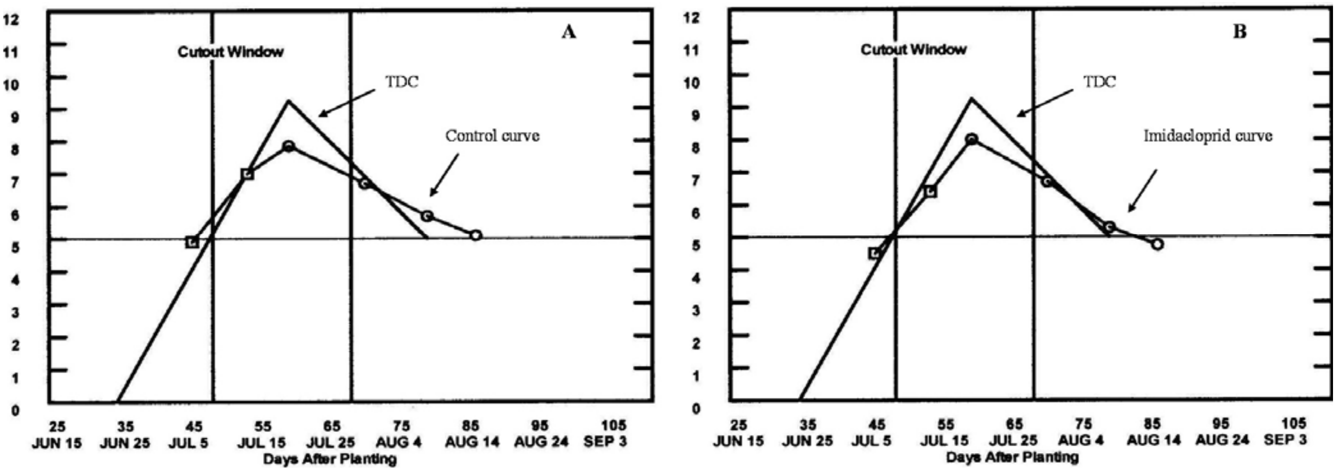

Fig. 2 COTMAN crop development pattern for (A) untreated control, and (B) imidacloprid applied three times starting at PHS, compared to the target development curve (TDC). 2004.

in the Trimax-treated plants compared to the untreated control (**Table 3**). The statistical analysis revealed no treatment × year interaction for the crop growth parameters measured, with P-values shown in **Table 3**.

The dry weight of leaves, stems, and fruit, as well as the percentage of the total dry weight of each treatment that these represent are presented in **Table 4** for 2004. Trimax applications significantly increased the dry weight of fruit, while the dry weight of leaves (P=0.093) and stems was only numerically increased (**Table 4**). When dry weights were expressed as a portion of the total dry weight for each treatment, applications of Trimax did not significantly alter the percentage that leaves contributed to the total dry weight. Conversely, Trimax significantly decreased the percentage of total dry weight for stems and significantly increased the percentage for fruit (**Table 4**).

Maturity

The crop monitoring software COTMAN predicted that the Trimax-treated plants reached the physiological maturity stage at nodes-above-white-flower-five, five days earlier in 2003 and three days earlier in 2004 (**Fig. 2**) compared to the untreated controls.

DISCUSSION

In this project the anecdotal reports of yield enhancement and growth improvement after Trimax (active ingredient: imidacloprid) applications were tested. Results showed that Trimax increased the productivity of field-grown cotton. This yield advantage was supported by the enhanced growth of Trimax-treated plants, as reflected in increased total dry weight and number of fruit per unit area. Foliar application of Trimax also resulted in earlier crop maturity, i.e. a shorter time to physiological maturity, compared to untreated plants.

Improved metabolism after Trimax application has been shown in growth chambers studies under controlled environmental conditions for different temperature regimes (Gonias *et al.* 2008). These authors showed positive effects of Trimax on chlorophyll fluorescence and photosynthesis which can explain the growth and yield advantage recorded in the present studies. They also reported a reduction in the activity of the antioxidant enzyme glutathione reductase after foliar application of Trimax, with the effect being significant at the higher temperature (39°C) of their study. Similarly, numerically reduced activity levels of glutathione reductase were also observed in both years of these field studies (data not published). However, relatively mild day temperatures (i.e., average 31°C) during the time of Trimax application possibly prevented statistically significant differences between treatments.

Overall, three applications of Trimax during early reproductive development had a positive effect on the cotton crop by improving growth and increasing lint yield. While there have been reports of growth and yield increases for other pesticides, such as aldicarb (Reddy *et al.* 1990), this is the first research showing a yield increase in cotton from Trimax in the absence of insects resulting from improved growth.

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