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EFFECTS OF BACILLUS CEREUS ON COTTON GROWTH AND YIELD

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Abstract

An important objective of Plant Growth Regulators (PGRs) is to balance vegetative and reproductive growth as well as improve yields and fiber quality. Various PGRs have been used to achieve these objectives with varying successes. Recently, *Bacillus cereus* (BC) was added to mepiquat chloride for additional yield advantage. The current research effort has focused on using BC with hormone based growth enhancer products for added growth and yield improvement. The new product, PGR-lV Plus, was tested over a four-year period in growth room studies and at 91 locations across the Cotton Belt on cotton that had received Pix Plus, resulting in an overall average 69.3 lb lint/acre increase in yield. Future studies will continue to evaluate *Bacillus cereus* in PGR-lV Plus for growth and yield advantages as well as in combinations with insecticides.

Introduction

Cotton is a major economic crop with an indeterminate growth habit, and is very responsive to environmental changes and management. Excessive vegetative growth results in shade within the plant canopy, increased fruit abscission, and reduced yield. Consequently, producers and researchers have long been interested in the use of plant growth regulators (PGRs) for adjusting plant vegetative growth and improving yield.

Pix Plus, formerly MepPlus, is a new PGR first tested in 1994 and registered in 1997 by Microflo (Memphis TN) and now marketed by BASF (Research Triangle Park, NC). It consists of mepiquat chloride (MC) (4.2%), the bacteria *Bacillus cereus* (0.05%) and inert ingredients (95.75%). The *Bacillus cereus* was reported to have tolerance exemption on all crops. Recent studies (Oosterhuis et al., 1998, Parvin and Atkins, 1997) have indicted that Pix Plus had a similar effect on plant height control as MC. In addition, Pix Plus has been reported to increased photosynthesis, leaf starch content, dry matter partitioning (Zhao and Oosterhuis, 2000), and lint yield (Parvin and Atkins, 1997) of field-grown cotton compared with the untreated control and MC treated plants.

Subsequent research showed that a combination of BC plus a hormone based formulation did enhance growth characteristics that influenced final yield. Growth chamber and field evaluations initiated in 1998 evaluated several formulations in either single or split applications. Favorable results were obtained and additional field trials began in 1999 refining proper rates and timing. Based on initial findings extensive field trials under the direction of certified crop consultants and university researchers began in 2000The hypothesis of this study is that the use of a combination of *Bacillus cereus* and mepiquat chloride will lead to increased efficacy of other hormone based products and improved plant growth and higher yields. The following is a summary of the results of these studies. The objectives of this project were to evaluate the benefits of applying *Bacillus cereus* with: *(a)* mepiquat chloride on yield and fiber quality, (b) a hormone based PGR (i.e. PGR-lV Plus) on yield and fiber quality, and (c) a pesticide on yield and fiber quality. In addition, we wanted to determine the optimum rate and timing of BC plus a PGR (PGR-lV Plus).

Materials and Methods

The Experiments Conducted Included

- 1998: Formulation studies at 17 field locations, plus growth room study.
- 1999: Formulation and timing studies at 20 field locations.
- 2000: Evaluation of a single timing at 33 field locations.
- 2001: Optimize formulation growth room study.

In all field studies, cotton (*Gossypium hirsutum* L.) was planted using current state extension recommendations for optimum cotton yield. Treatments included: (1) an untreated control, (2) Pix Plus as needed for height control, and (3) PGR-IV Plus (*Bacillus cereus*). The spray applications were made using aerial application or backpack sprayer calibrated to deliver 93.5 L/ha in University small plot studies and consultant field trials.

Results and Discussion

Bacillus cereus and PGR-IV Plus

Bacillus cereus (BC) was originally identified as having PGR effects, i.e., improved partitioning and translocation of carbohydrates to fruits (Zhao and Oosterhuis, 2001). BC was subsequently mixed with mepiquat chloride (MC) at rates of 1x to 4x

to improve yield while still providing vegetative control. The 2x rate was generally the best, but some locations responded best to the higher rates. Subsequently, combinations of BC + PGR-lV were tested in 1998-2001 on cotton that had been (or would be) treated with Pix Plus. From these studies, PGR-lV Plus was formulated. The overall results support the hypothesis of additional yield from improved partitioning of carbohydrates to the fruit.

1998: Formulation Study

Five formulations of varying concentrations of PGR-IV with *Bacillus cereus* (PGR-IV Plus) were evaluated at 17 sites in either single or split applications. All formulations, except one, had a higher percentage of sites that ranked in the top three versus Pix Plus. Based on these trials, the formulation with the highest percent (76%) of sites ranking in the top three was selected for additional evaluations.

1999: Rate and Timing Trials

Twenty sites across the Cotton Belt were used to evaluate the selected formulation from the 1998 trials. The sites included six from Mississippi, six from South Carolina, six from Texas, four from Louisiana, two from Arkansas, one from Missouri, and one from California. Single and split applications of PGR-lV Plus were made to cotton that had or would be treated with Pix Plus. Timings included pinhead square (PHS), early bloom (EB), and early bloom + 3 weeks (EB + 3). Split applications of the single applications were also made. Single applications at PHS and EB had the highest yield as compared to the Pix Plus treatment. Average yield increase across 20 sites ranged from 30 to 62 lb lint/acre. Bloom applications were the most consistent across all locations with 75% of sites ranking in the top three.

2000: Dry Formulation Evaluation

To insure product efficacy and extend shelf life, a dry formulation containing the same active ingredients was developed. Thirty three sites under the supervision of independent cotton consultants evaluated this product. Twenty five consultants in the Tri-State Delta and eight consultants in Texas made single applications at early bloom at 1 ounce or 1.5 ounces per acre to cotton that had been or would be treated with Pix Plus. Average yields for the one ounce rate were 1062 lbs lint/acre versus 982 lbs lint/acre for Pix Plus. The average yields for the 1.5 ounce rate were 1048 lbs lint/acre versus 992.0 lbs lint/acre for Pix Plus. The dry formulation of PGR-IV Plus proved to be highly efficacious with regards to both yield and consistency. Cotton treated with Pix Plus and subsequently treated with PGR-IV Plus had increased yields of 9.2% lint at the one ounce/acre rate, and 5.9% lint at the one and one half ounce/acre rate. Consistency was greatly increased with 93.9% of sites having increases with the one ounce rate.

2001: Growth Chamber and Rate Response

Previous growth chamber and rate response studies were evaluated and further testing was initiated. Both growth chamber and field trials have indicated that the *Bacillus cereus* component increases carbohydrate partitioning mainly to the fruiting structures, i.e., squares and bolls (Zhao and Oosterhuis, 2000). Additional dry matter partitioning studies are on going at this time. Field rate response trials conducted in 2001 again proved that applications of PGR-IV Plus at PHS, EB or EB + 3 weeks have a positive yield effect on cotton that has been treated with Pix Plus or mepiquat chloride. Percent yield increases by application timing were as follows: pinhead square 6.0%, early bloom 7.2%, and early bloom + 3 weeks 8.7% versus mepiquat-chloride applications.

Increased Yields from PGR-lV Plus Over the Area Standard

- 1999 University and Consultants: Average yield increase 46 lint/acre.
- 2000 MS Delta Consultants: Average yield increase 70 lint/acre.
- 2000 TX Consultants: Average yield increase 67 lint/acre.
- 2002 MS Delta University and Consultants: Average yield increase 76 lint/acre.

In general, overall five years and 91 locations, a 69.3 lb lint /acre yield increase was achieved.

2002 Field Studies: PGR-lV Plus Alone and in Combination with a Pesticide

Field studies in 2002 showed that PGR-lV Plus out yielded the control by 70 lb. lint/acre (+6.1%) for the 1.0 oz/acre rate and by 83 lb lint/acre (+8.2%) for the 1.5 oz/acre rate (Table 1). These results are in agreement with those from the previous three years.

Field studies in 2002 showed that Bacillus cereus with acephate out yielded the control by 41 lb. lint/acre (+3.4%) for the 0.5 oz/acre rate and by 45 lb lint/acre (+3.7%) for the 0.75 oz/acre rate (Table 1). These results show the positive results from combining *Bacillus cereus* with a pesticide, presumably through improved translocation.

Theory Behind the *Bacillus cereus* Hormone Combination

The theory behind the *Bacillus cereus* hormone combination is that maximum plant uptake rates of nutrients and carbohydrate rates occur during the squaring and early flowering period (fig.1). Therefore enhancement of partitioning and translocation during this period should benefit yield, particularly under stressful conditions.

Physiological Studies

Earlier studies by Zhao and Oosterhuis (2000) showed that the new plant growth regulator Pix Plus, consisting of *Bacilus cereus* and mepiquat chloride, improved translocation of photoassimilates from leaves to fruits and partitioning of dry matter among plant tissues, resulting in improved yields (Fig. 2).

Future Research

Since we have obtained such positive results combining *Bacillus cereus* with mepiquat chloride, PGR-lV and pesticides, field testing will continue with additional emphasis on improving our understanding of the mechanism of these combinations.

Conclusions

Earlier addition of Bacillus cereus to mepiquat chloride resulted in improved partitioning and carbohydrate translocation to the fruit. Subsequent combinations *of Bacillus cereus* and a hormone PGR-lV resulted in additional yield increases in field and growth room studies over a four year period at 71 locations across the Cotton Belt. Optimum timing of PGR-lV Plus application was achieved with early- to mid-bloom applications. These studies have shown activity of *Bacillus cereus* with growth retardants, PGR enhancers and insecticides.

References

Zhao, D. and Oosterhuis, D.M. 2000. Pix Plus and mepiquat chloride effects on physiology, growth, and yield of field-grown cotton. Journal of Plant Growth Regulation.19:415-422.

Oosterhuis, D.M., Zhao, D. and Murphy, J.B. 1998. Physiological and yield responses of cotton to MepPlus and mepiquat chloride. pp. 1422-1424. In Heber, D.J. and Richter, D.A. (Eds.) Proceedings Beltwide Cotton Conferences. National Cotton Council of America, Memphis, TN.

Table 1. Effect of PGR-lV Plus on Yield averaged over 20 Locations in 2002.

Treatment	Lint Yield	
	1.0 oz/acre	1.5 oz/acre
Control	1127	1009
PGR-IV Plus	1196	1092
Difference	70 (+6.1%)	83(+8.2%)

Table 2. Effect of *Bacillus cereus* with Acephate on Yield averaged over 18 Locations.

Treatment	Lint Yield	
	0.5 oz/acre	0.75 oz/acre
Orthene	1204	1216
AcePlus	1245	1261
Difference	41 (+3.4%)	45(+3.7%)

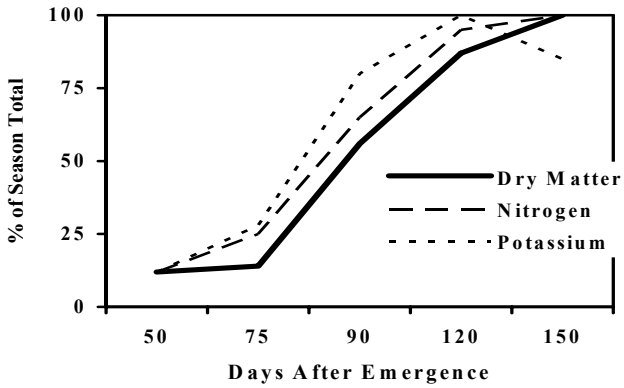

Figure 1. Dry matter accumulation curve for cotton showing the zone of maximum requirements in relation to application times for PGRs to aid partitioning to the fruit. The optimum timing time of application of PGR-lV Plus is between pinhead square and early flowering, but no later than 3 weeks after flowering.

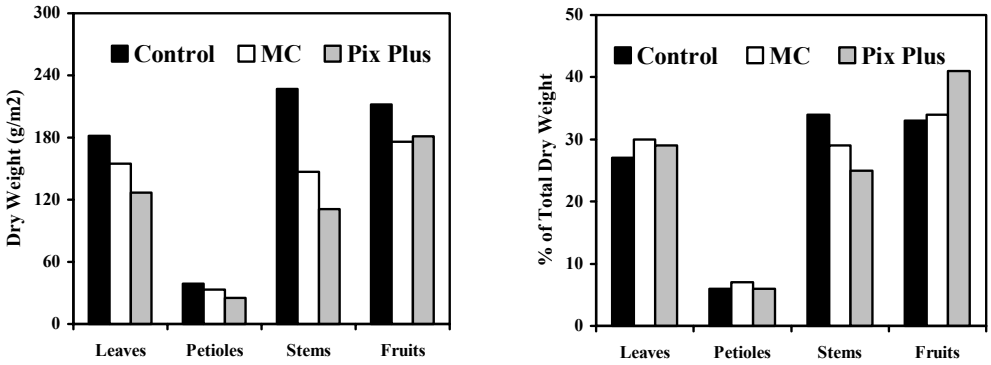

Figure 2. Effect of Mepiquat Chloride and Pix Plus on dry matter accumulation and partitioning of field-grown cotton (From Zhao and Oosterhuis, 2000).