EFFECT OF 1-METHYLCYCLOPROPENE ON UPLAND COTTON

A Thesis

by

JUSTIN JACK SCHEINER

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2007

Major Subject: Molecular and Environmental Plant Sciences

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Approved by:

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ABSTRACT

Effect of 1-Methylcyclopropene on Upland Cotton.

(May 2007)

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Ethylene plays a key role in square and boll abscission in cotton (*Gossypium hirsutum* L.). When subjected to stress, cotton plants synthesize higher rates of ethylene which can result in the loss of immature fruit. The ethylene action inhibitor 1-methylcyclopropene (1-MCP) is used in many fruit, vegetable, and floriculture crops to counter the effects of ethylene. Protecting a cotton crop from ethylene through its early reproductive stages may boost yields by increasing fruit retention. A two-year field study was conducted in 2005 and 2006 at the Texas Agricultural Experiment Station in Burleson County, Texas to evaluate the effects of 1-MCP concentration and timing on cotton growth and yield components.

The study was designed as a randomized complete block with 4 replications. Three rates of 1-MCP (250, 500, and 1250 g ha^{-1} of actual product) were applied as a foliar spray at a delivery rate of 93.50 L^{-1} ha. Each rate was applied at pinhead-square and fourteen days after pinhead-square; pinhead-square, fourteen days after pinhead-square, and early bloom; early bloom and fourteen days after early bloom; early bloom, fourteen days after early bloom, and twenty-eight days after early bloom. Plant heights, total number of nodes per plant, percent square abscission, nodes above white flower

(NAWF), relative chlorophyll content, fruit number, fruit size, and fruit distribution were not affected by 1-MCP. In 2006, electrolytic leakage was significantly increased by two, 250 g ha^{-1}, 1-MCP treatments. In 2005, yield was significantly increased by six of the 1-MCP treatments and suggests an increase in boll retention, boll size, seed number, or seed size. The analysis of yield components conducted through box-mapping, however, failed to explain the observed yield response. In 2006, 1-MCP did not significantly influence yield.

DEDICATION

This thesis is dedicated to my family and friends who have provided support, patience, and understanding throughout this degree.

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TABLE OF CONTENTS

Page

ABSTRACT iii

DEDICATION v

ACKNOWLEDGEMENTS vi

TABLE OF CONTENTS vii

LIST OF TABLES ix

INTRODUCTION 1

- Literature Review 1
- Ethylene 2
- Ethylene and Abscission 2
- Ethylene and Senescence 3
- Stress Ethylene 4
- Ethylene Synthesis and Perception 4
- Ethylene Signal Transduction 5
- 1-Methylcyclopropene 6
- Effects of 1-Methylcyclopropene 6
- Treatment Parameters 7
- Objectives 8

MATERIALS AND METHODS 9

- Cultural Practices 9
- Treatments 9
- Data Collection 11
- Statistical Analysis 14

RESULTS AND DISCUSSION 15

- Box-mapping 27
- Yield 43

CONCLUSIONS 53

REFERENCES 55

Page

APPENDIX A 65

APPENDIX B 67

VITA 69

LIST OF TABLES

Page

Table 1 List of treatments, rates, and growth stage of application for 2005 and 2006 10

Table 2 Plant heights and total number of nodes, one day prior to pinhead-square 16

Table 3 Effect of 1-methylcyclopropene (1-MCP) on plant height, total number of nodes, percent square shed, relative chlorophyll content (SPAD), and nodes above white flower (NAWF), thirteen days after pinhead-square 18

Table 4 Effect of 1-methylcyclopropene (1-MCP) on plant heights, total number of nodes, and percent square shed, one day prior to early bloom 20

Table 5 Effect of 1-methycyclopropene (1-MCP) on relative chlorophyll content (SPAD), nodes above white flower (NAWF), plant heights, total number of nodes, and percent square, thirteen days after early bloom 22

Table 6 Effect of 1-methylcyclopropene (1-MCP) on nodes above white flower, plant heights, total number of nodes, relative chlorophyll content (SPAD), and percent square shed, twenty-seven days after early bloom 24

Table 7 Effect of 1-methylcyclopropene (1-MCP) on relative chlorophyll content (SPAD) and electrolytic leakage, forty-five days after early bloom, 2006 26

Table 8 Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 3 through 5, 2005 28

Table 9 Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 3 through 5, 2006 29

Table 10 Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 6 through 10, 2005 30

Page

Table 11 Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 6 through 10, 2006 31

Table 12 Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 11 through 15, 2005 33

Table 13 Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 11 through 15, 2006 34

Table 14 Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 16 through 20, 2005 35

Table 15 Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 16 through 20, 2006 36

Table 16 Effect of 1-methylcyclopropene (1-MCP) on first position number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant, 2005 37

Table 17 Effect of 1-methylcyclopropene (1-MCP) on first position number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant, 2006 38

Table 18 Effect of 1-methylcyclopropene (1-MCP) on second position number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant, 2005 39

Table 19 Effect of 1-methylcyclopropene (1-MCP) on second position number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant, 2006 40

Table 20 Effect of 1-methylcyclopropene (1-MCP) on third position number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant, 2005 41

Page

Table 21 Effect of 1-methylcyclopropene (1-MCP) on third position number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant, 2006 42

Table 22 Effect of 1-methylcyclopropene (1-MCP) on total number of bolls, percent of total bolls, total boll weight, mean boll weight per plant on monopodial branches, 2005 44

Table 23 Effect of 1-methylcyclopropene (1-MCP) on total number of bolls, percent of total bolls, total boll weight, mean boll weight per plant on monpodial branches, 2006 45

Table 24 Effect of 1-methylcyclopropene (1-MCP) on plant height, total nodes, height to node ratio, total number of bolls and total boll weight per plant, 2005 46

Table 25 Effect of 1-methylcyclopropene (1-MCP) on plant height, total number of nodes, height to node ratio, total number of bolls and total boll weight per plant, 2006..... 47

Table 26 Effect of 1-methylcyclopropene (1-MCP) on seedcotton yield, gin turnout, and lint yield, 2005 48

Table 27 Effect of 1-methylcyclopropene (1-MCP) on seedcotton yield, gin turnout, and lint yield, 2006 50

Table 28 Effect of 1-methycyclopropene (1-MCP) on lint quality parameters, 2005 51

Table 29 Effect of 1-methycyclopropene (1-MCP) on lint quality parameters, 2006 52

INTRODUCTION

Literature Review

Cotton (*Gossypium hirsutum*, L.) yield is directly correlated with the number and size of bolls per given area (Worley et al., 1974; Hake et al., 1992a). It is crucial to provide an optimal growing environment throughout the early reproductive period due to cottons' high susceptibility to shed reproductive organs (Guinn, 1982). Numerous factors associated with square and boll shed have been identified, including: extreme temperatures (Reddy et al., 1999; Zhao et al., 2005); low light conditions (Eaton and Rigler, 1945; Goodman, 1955; Guinn, 1981); poor fertility (Hake et al., 1989b); drought stress (McMichael and Jordan, 1973; McMichael, 1979; Guinn, 1982; Hake et al., 1992b); and insect pressure (Gaines, 1957; Holman and Oosterhuis, 1999). Research has demonstrated that any one of these factors is capable of inducing significant square and boll loss and therefore decreasing overall yield. However, under favorable conditions, cotton has the ability to compensate for early season shed (Sadras and Wilson, 1998; Wilson et al., 2003) by extending its reproductive phase (Hake and Meredith, 1990). Complete compensation was observed when all fruit had abscised from the first four reproductive nodes with no loss of yield (Wilson et al., 2003). Even though early season fruit shed can be overcome by setting fruit higher on the plant (Malik et al., 1981; Hake and Meredith, 1990), it can present problems at harvest.

In the United States a timely harvest is essential to avoid inclement weather commonly seen in the later part of the growing season (Hake and Meredith, 1990; Lange

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This thesis follows the style of *Crop Science*.

and Hake, 1992; Hake et al., 1992a). A late maturing crop may suffer decline in lint quality and yield due to lint staining, lint drop, and premature termination from rainfall and early freezing temperatures (Hake et al, 1989a; Lange and Hake, 1992; Hake et al., 1992a). The above demonstrate the importance for protecting the plants from early season shed. Previous research indicates that early season square and boll abortion is at least partially due to ethylene evolution (Lipe and Morgan 1972; Guinn, 1975; Guinn, 1976).

Ethylene

Ethylene (C_2H_4) is a gaseous plant hormone (Crocker et al., 1935) involved in a wide range of physiological processes that range from seed germination to apoptosis (Mattoo and Suttle, 1991). The capability of higher plants to produce ethylene is evident in all tissues (Yang and Hoffman, 1984). The rate at which ethylene is synthesized varies among plant tissues and is affected by the age of the respective tissue (Ableles, 1973). Also, many biotic and abiotic stresses elicit an increase in ethylene synthesis (Lieberman, 1979). Data suggest that ethylene plays a major role in abscission and senescence of cotton fruit (Jordan et al., 1972; Lipe and Morgan, 1972; Abeles, 1973; Mattoo and Suttle, 1991). Because boll retention is the primary factor in cotton yield (Worley et al., 1974; Wells and Meredith, 1983; Hake et al., 1992b,), it is important to protect a crop from ethylene induced fruit shed.

Ethylene and Abscission

Studies indicate that ethylene mediates abscission in leaves (Jackson and Osborne, 1970; Suttle and Hultstrand, 1991; Morgan et al., 1992), floral parts (Morgan,

1969), and fruit (Lipe and Morgan, 1972; Guinn, 1981). Ethylene stimulates the production of hydrolytic enzymes in the abscission zone that initiate cell separation in the abscission layer (Horton and Oosterhuis., 1967; Abeles, 1968; Moore, 1968; Abeles, 1969). Ethylene-mediated abscission is dependent upon the tissue's sensitivity to ethylene which varies among species and tissues (Abeles, 1973). Morgan (1969) found that concentrations of ethylene too low to cause leaf abscission in cotton caused young flower buds and fruit to abscise suggesting a greater degree of sensitivity in young reproductive parts of cotton.

Ethylene and Senescence

Senescence is a process where cells undergo changes in structure, metabolism, and gene expression that eventually lead to cell death (Gan and Amasino, 1997). Ethylene acts as an accelerator of senescence (Burg, 1968). Numerous studies show that ethylene enhances chlorophyll degradation (Gepstein and Thimann, 1981; Kao and Yang, 1983; Bleecker and Patterson, 1997; Jiang et al., 2002a), the first identifiable step in senescence (Taiz and Zeiger, 2006). Degradation of chlorophyll is primarily through action of the chlorophyllase enzyme (Tsuchiya et al., 1999) which is synthesized at higher rates in the presence of ethylene (Wilk et al., 1999). Ethylene also increases membrane permeability (Suttle and Kende, 1980; Faragher et al., 1986) causing electrolyte leakage. Studies show that when ethylene action is blocked, senescence processes can be prolonged in leaves (Jiang et al., 2002a; Willis et al., 2002), flowers (Sisler et al., 1996; Iieyes and Johnston, 1998), and fruit (Porat, et al., 1999; Feng et al., 2000).

Stress Ethylene

Many biotic and abiotic stresses elicit ethylene synthesis (Abeles, 1973). Previous research has shown stimulation in ethylene synthesis by pathogen (Walling, 2000; Kruzmane et al., 2002;), temperature (Cooper et al., 1969; Yang and Hoffman, 1984;), water (McMichael et al., 1972; Kawase, 1978; Apelbaum and Yang, 1981; Beltrano et al., 1999;), light (Rikin, 1984), mechanical (Hanson and Kende, 1976; Yu and Yang, 1980), nutritional (Guinn, 1976; Lege et al., 1997), and chemical (Morgan and Hall, 1964; Morgan, 1969) stress. In cotton, research demonstrates that plants subjected to drought (McMichael et al., 1972; Guinn, 1975) and insect stress (Martin et al., 1988) synthesize rates of ethylene that are capable of inducing leaf and boll abscission.

Ethylene Synthesis and Perception

Ethylene is synthesized from *S*-adenosyl-L-methionine (S-AdoMet) and 1-aminocyclopropane-1-carboxylic acid (ACC) (Adams and Yang, 1979). Two enzymes catalyze this reaction: ACC synthase and ACC oxidase (Kende, 1993). In the reaction converting S-AdoMet to ACC, the methyl group is preserved at the cost of one adenosine triphosphate. This would enable large quantities of ethylene to be synthesized even if large quantities of free methionine were not available (Wang et al., 2002). Because the expression of ACC synthase is regulated by various developmental, environmental and hormonal signals, it is regarded as the limiting enzyme in ethylene biosynthesis (Kende, 1993). According to Bleecker and Kende (2000), ethylene perception can inhibit seed growth in 10 to 15 minutes and enhance the synthesis of

enzymes in a matter of hours. A response can be generated from nanomolar concentrations of ethylene, indicating a high affinity for the receptor (Bleecker and Kende, 2000). Research using Arabidopsis mutants has shown that ethylene signaling is mediated by a family of ethylene receptors (Hirayama et al., 1999; Rodriguez et al., 1999) and that localization of the ETR1 receptor family occurs in the endoplasmic reticulum (Chen et al. 2002). The binding domain has an electron-rich hydrophobic pocket formed by membrane spanning helices that coordinate a copper cofactor. The copper cofactor interacts directly with ethylene (Bleecker, 1999). When ethylene is bound, the coordination chemistry of the copper (I) cofactor is altered thus generating a transcriptional cascade (Bleecker and Kende, 2000).

Ethylene Signal Transduction

Several molecules have been identified as negative and positive regulators of the ethylene response pathway. The signaling kinase, CTR1, is an 821-amino acid protein having a kinase domain localized in the C-terminal (Kieber et al., 1993). CTR1 functions as a negative regulator (Kieber et al., 1993) and encodes a putative protein kinase that acts downstream of ethylene receptors (Roman et al., 1995; Kieber, 1997) In yeast, the ethylene receptors ETR1 and ERS1 have been shown to interact directly with CTR1 (Clark et al., 1998). EIN2 and EIN3 are proteins that act downstream of CTR1 (Johnson and Ecker, 1998). Phenotypic and epistasis analyses in Arabidopsis indicate that EIN2 is in a central position in the ethylene signaling pathway (Johnson and Ecker, 1998). EIN3 is localized in the nucleus and acts downstream of EIN2 (Roman et al., 1995). It is

suggested that EIN3 is a direct regulator of transcription factors that control ethylene-regulated genes (Johnson and Ecker, 1998).

1-Methylcyclopropene

1-methlycyclopropene (1-MCP) is an ethylene action inhibitor (Sisler and Serek, 1997). At standard pressure and temperature it is a gas with a formula of C_4H_6. 1-MCP can block ethylene action at low concentrations due to its high affinity (approximately 10 times that of ethylene) for ethylene receptors (Blankenship and Dole, 2002). It is also believed that 1-MCP binds to the receptor site permanently thereby blocking ethylene (Sisler and Serek, 1999). Because 1-MCP has a different chemical structure than ethylene, it does not elicit an ethylene-like response when bound to the receptor (Blankenship and Dole, 2002).

Effects of 1-methylcyclopropene

1-MCP has proven to be a useful tool in the horticulture industry by blocking the deleterious effects of ethylene. A variety of beneficial physiological effects have been observed in fruits, flowers, and plants treated with 1-MCP including: decreases or inhibition of ethylene production (Abdi et al., 1998; Jiang et al., 2001; Fan and Mattheis, 1999a; Dong et al., 2001; Jeong et al., 2002;), chlorophyll degradation (Porat et al., 1999; Ku and Willis, 1999; Fan and Mattheis, 1999b; Fan and Mattheis, 2000; Jiang et al., 2002a), membrane leakage (Serek et al., 1995a; Jiang et al., 2002b), respiration (Abdi et al., 1998; Tian et al., 2000; Fan and Mattheis, 2000; Dong et al., 2001;), volatile production (Abdi et al., 1998; Golding et al., 1998; Fan and Mattheis, 2001; Jiang and Joyce, 2002; Flores et al., 2002;), fruit softening (Rupasinghe et al.,

2000; Baritelle et al., 2001; Hofman et al., 2001), tissue weight loss (Porat et al., 1999; Jeong et al., 2002), abscission rate (Michaeli et al., 1999), and reduced occurrence of disease and injury (Fan et al., 1999; De Wild et al., 1999) as well as increases in sugar content (Watkins et al., 2000; Hofman et al., 2001; Selvarajah et al., 2001). However, these effects appear to be species dependent. Some tissues treated with 1-MCP exhibited increased ethylene production (Selvarajah et al., 2001; Jiang et al., 2002a), increased respiration (Fan and Mattheis, 2001; Jiang et al., 2002b), decreased sugar content (Watkins et al., 2000), and increased infection and rotting (Ku et al., 1999; Jiang et al., 2001).

Treatment Parameters

In most studies 1-MCP was applied at temperatures between 20 to 25ºC (Blankenship and Dole, 2002). Data suggest a relationship exists between temperature, time, and concentration of treatment (Sisler and Serek, 1997; DeEll et al., 2002; Jiang et al., 2002a). Application of 1-MCP was generally not as effective at temperatures less than 10 ºC (Serek et al. 1995a; Ku et al., 1999; Jiang et al., 2002a). This has been attributed to low ethylene sensitivity (Mir et al., 2001). Most treatments of 1-MCP have been in enclosed environments enriched with the gas (Blankenship and Dole, 2002). The most effective concentration at which 1-MCP is applied varies among species. It was found that 2.5 nl L^{-1} effectively inhibited ethylene action in carnations (Sisler et al., 1996) while 1 µl L^{-1} was necessary for complete protection of apples (Jiang and Joyce, 2002). Most studies show that treatment durations of less than 12 hours do not provide sufficient protection (Ku et al., 1999; Jeong et al., 2002). Blankenship and Dole (2002)

suggest that treatment duration of 12 to 24 hours is needed to protect most species. It has been shown that 1-MCP effectively protects plants from both endogenous and exogenous ethylene, but sometimes multiple applications are required. Due to the belief that binding of 1-MCP is permanent, a plant's return to sensitivity has been attributed to the regeneration of receptor sites (Serek et al., 1995b; Blankenship and Dole, 2002).

Objectives

Cotton is highly susceptible to early season fruit shed. This fruit shed has been linked to ethylene evolution in response to stress. Fruit loss can result in yield reduction and delayed maturity (Hake and Meredith, 1990). Previous studies with 1-MCP have demonstrated its effectiveness in blocking the effects of ethylene. These findings warrant an investigation to determine if 1-MCP can effectively protect cotton against fruit loss.

The specific objectives of this study were to evaluate the effects of 1-MCP concentration and timing on cotton yield parameters, and determine if the application of 1-MCP has an effect on senescence processes: chlorophyll degradation and electrolytic leakage.

MATERIALS AND METHODS

Cultural Practices

In 2005 and 2006 a two-year field study was conducted at the Texas Agricultural Experiment Station (TAES) in Burleson County, Texas. Field plots were located in the Brazos River Bottom on a Weswood silt loam (fine-silty, mixed, superactive, thermic, Udifluventic Haplustepts), having a pH of 8.2.

Prior to planting, urea ammonium nitrate solution (32-0-0) was injected below the soil surface at a rate of 135 kg ha^{-1}. Delta and Pine Land 449BR and Stoneville 4554 B2RF were planted in 2005 and 2006 respectively, with a John Deere MaxEmerge Plus Vacuum planter. Seeding rate for both years was 128,440 seeds ha^{-1}. Plots were irrigated as needed via an overhead lateral sprinkler system. Pesticide applications (Appendices A and B) and all other cultural practices were compliant with Texas Cooperative Extension recommendations for Burleson County.

Treatments

To account for any variation in the field, a randomized complete block design was selected. Plots consisted of four 1.02-m rows x 9.75-m in length. The fourteen treatments that comprised this study and their respective rates and timings are shown in Table 1. All treatment applications were applied as a foliar spray with 140.2 L ha^{-1} of water using a compressed air small plot sprayer equipped with Tee Jet® (Spraying Systems Inc.) XR 8002 VS flat-fan nozzles at 51-cm nozzle spacing. The 1-MCP compound used in this study was a soluble powder with 2 % active ingredient. When the compound is dissolved in water, 1-MCP is released.

Table 1. List of treatments, rates, and growth stage of application for 2005 and 2006.

Treatment†	Rate‡	Growth Stage§	Abbreviation¶
1-MCP	250 g ha^{-1}	PHS & PHS+14	LPHS2
1-MCP	250 g ha^{-1}	PHS & PHS+14 & EB	LPHS3
1-MCP	250 g ha^{-1}	EB & EB+14	LEB2
1-MCP	250 g ha^{-1}	EB & EB+14& EB+28	LEB3
1-MCP	500 g ha^{-1}	PHS & PHS+14	MPHS2
1-MCP	500 g ha^{-1}	PHS & PHS+14 & EB	MPHS3
1-MCP	500 g ha^{-1}	EB & EB+14	MEB2
1-MCP	500 g ha^{-1}	EB & EB+14& EB+28	MEB3
1-MCP	1250 g ha^{-1}	PHS & PHS+14	HPHS2
1-MCP	1250 g ha^{-1}	PHS & PHS+14 & EB	HPHS3
1-MCP	1250 g ha^{-1}	EB & EB+14	HEB2
1-MCP	1250 g ha^{-1}	EB & EB+14& EB +28	HEB3
UTC	N / A	N /A	UTC
Surf	0.09 L ha^{-1}	EB & EB+14& EB+28	Surf

† Chemical treatment: 1-MCP, 1-methycyclopropene; UTC, untreated check; Surf, surfactant.
‡ Chemical rate: N/A, none.
§ Stage of growth at which plants received over the top application of chemical treatment: PHS, pinhead-square; PHS+14, 14 days after pinhead-square; EB, early bloom; EB+14, 14 days after early bloom; EB+28, 28 days after early bloom; N/A, no application timing.
¶ Abbreviations to be referred to in graphic figures at the results section.

Data Collection

Data collected from both years of this experiment included a variety of vegetative, reproductive, and senescence measurements including: plant heights, total plant node counts, percent square shed, nodes above white flower (NAWF), SPAD meter readings, box-mapping, lint yield, and fiber quality. In addition, electrolytic leakage measurements were collected in 2006.

Plant heights and total number of nodes were measured from ten randomly selected plants from the second row in each plot prior to each 1-MCP application. All plant height measurements were taken from the cotyledonary nodes to the plant apex. Node counts were taken beginning at the first node above the cotyledonary nodes to the upper most fully expanded leaf with a diameter of at least 2.5 cm. SPAD meter readings were taken from two randomly selected plants from the second row in each plot. The average of three SPAD measurements was noted from the third leaf below the uppermost fully expanded leaf. A SPAD meter emits light onto the upper surface of the leaf at wavelengths of 650 (red) and 940 (infrared) nanometers, respectively. The light enters the interior of the leaf where it is absorbed by the chlorophyll. The amount of light transmitted through the leaf is measured by a silicon photodiode detector. As a result, an arbitrary determination of chlorophyll content is given as an inverse of the transmitted light. Nodes above white flower (NAWF) value were determined in each plot by counting the total nodes above the uppermost white flower in the first position from ten randomly selected plants in each plot. An average was calculated from each plot to determine physiological maturity of the crop. Physiological maturity is presumed to

occur at NAWF = 5 (Bourland et al., 1992).

Percent square shed was assessed in both years using COTMAN III (Cochran et al., 1998). Data collection consisted of counting the total number of first position squaring sites and the total number of first position squares that had been abscised from ten randomly selected plants in each plot.

In both years a variation of box-mapping as described by Jenkins and McCarty (1995) was conducted prior to crop harvest. Box-mapping consisted of measuring plant heights, total number of nodes, boll retention and boll weight by respective position within the canopy. Height measurements were taken from the cotylendonary nodes to the apex of the plant. The first fruiting node was noted. The total number of nodes was determined from the first nodes above the cotyledonary nodes to the apex of the plant. Total number of bolls and boll weight were measured by position and node to determine yield distribution. In 2005, box-mapping was conducted from six randomly selected plants in the plot. In 2006, ten randomly selected plants were box-mapped in an attempt to obtain a more accurate representation of the total yield.

In 2006 electrolytic leakage was measured for each plot. Three leaf disks which were 3.03-cm^2 in diameter, were extracted from the third leaf down from the apex of three randomly selected plants. Disks were placed in 10 ml of de-ionized water and incubated at 25°C for 1 hour. Electrical conductivity of the solution was measured with a conductivity meter (Oakton Instruments, Vernon Hills, Illinois, USA). The leaf disks were then incubated at 40°C for 1 hour and electrical conductivity was again measured for each. A third and final measurement of electrical conductivity was taken after leaf

disks were subjected to an incubation period of 20 minutes at 120°C to determine total solute concentration. Electrolytic leakage was determined as a percent of total solutes following incubation at 1 hour 25°C and 1 hour 40°C. Electrolytic leakage is a measure of membrane integrity and therefore utilized as an indicator of degree of plant senescence.

Harvest aids (Appendices A and B) were applied in both years prior to harvest when the crop averaged 60% open boll. Rows two and three of each plot were machined harvested with a two-row spindle picker two weeks after harvest aid application. Harvested cotton from each row was weighed and averaged over the two rows for each plot to determine seed cotton yields. A 150 g sub-sample was extracted from each plot and ginned with a ten-saw, hand-fed, portable gin to determine lint turnout. After ginning, 50-g samples were collected from each plot and subjected to High Volume Instrument (HVI) testing at the International Textile Center in Lubbock, Texas to determine lint quality and characteristics. Classification was based on physical attributes: micronaire, length, strength, uniformity, reflectance (Rd), and degree of yellowness (+b). Micronaire is a measure of fiber fineness and is influenced by moisture, temperature, plant nutrients, sunlight, nutrition, and extremes in plant or boll population. Fiber length is determined by the length of the longest one half of the fibers in a sample. Length is based on the variety of cotton and is influenced by the plants exposure to extreme temperatures, water stress, and nutrient deficiencies. The uniformity of length is also measured in a sample by a ratio of mean length and the upper half mean length of the fiber. Fiber strength is measured as the force required to break a bundle of fibers one tex

(weight in grams of 1,000 m of fiber) in size. Rd and +b are color grades of the sample and are determined by how bright or how dull the fiber is and the pigmentation. Color grade is affected by rainfall, freezes, insects, fungi, and staining (USDA, 1993).

Statistical Analysis

Collected data were analyzed using SAS® statistical software (SAS Institute, 1999-2000). Data was subjected to the Proc GLM procedure and means were separated using the Fischer's protected least significant difference (LSD) at the 5% significance level. Data were combined over years if no significant year by treatment interaction was present. SPAD data were not analyzed over years due to non-corresponding measurement timings. Box-mapping data were not analyzed by year due to the differing number of plants selected in 2005 and 2006.

RESULTS AND DISCUSSION

Application timings of 1-MCP were determined from previous research regarding cotton's sensitivity to fruit shed. Studies indicate that cotton squares (Eaton and Rigler, 1945; McMichael, 1979) and young bolls (Morgan, 1969; McMichael et al., 1973) are the most sensitive to ethylene-mediated abscission. Therefore, applications of 1-MCP were initiated at pinhead-square (PHS) and early bloom (EB). Depending on the treatment, one or two additional applications were made in fourteen-day increments to block ethylene perception in an effort to enhance yield components at their most sensitive stage of development.

The initial plant growth measurements were taken one day prior to the first application of 1-MCP which occurred at PHS. Plant heights and number of nodes were measured in each plot to assure crop uniformity across the study. Due to variation between years, significant year x treatment interaction was observed for plant heights. Therefore, the results are reported by year. In 2005, plant heights ranged from 35.6 to 41.2 cm across treatments one day prior to pinhead-square, and were not significantly different (Table 2). Plants were shorter in 2006 and ranged from 17.8 to 22.3 cm. Significant differences were observed among treatments for plant heights; however, the variation was slight and it is believed that these differences did not influence the results of this study. The difference in plant height between years could possibly be attributed to varietal characteristics. The variety planted in 2005, Delta and Pineland 449BR, is a mid-season maturing variety and the variety planted in 2006, Stoneville 4554B2F, is an

Table 2. Plant heights and total number of nodes, one day prior to pinhead-square.

	Plant height		Total nodes
	2005	2006	
	——————cm——————		——nodes plant^{-1}——
Treatment†			
LPHS2	37.1a‡	17.8e	6.80a
LPHS3	37.2a	18.3de	6.83a
LEB2	37.5a	19.3b-e	6.99a
LEB3	36.7a	19.8b-e	6.99a
MPHS2	39.1a	19.0b-e	6.85a
MPHS3	37.6a	18.8b-e	7.06a
MEB2	37.7a	19.8b-e	6.87a
MEB3	40.1a	20.1bcd	7.03a
HPHS2	36.6a	20.1bcd	7.03a
HPHS3	37.9a	20.7abc	6.92a
HEB2	36.2a	22.3a	7.10a
HEB3	35.7a	18.6cde	7.00a
UTC	35.6a	20.8ab	7.23a
SURF	37.8a	18.4de	6.94a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.

‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

early mid-season variety. The total number of nodes was also counted from the above mentioned plants and data were pooled over years for analysis. The average number of nodes per plant was approximately 7 for all treatments with no significant differences observed.

Ethylene's role in abscission has been well documented. However, its function in other plant processes has not been fully defined. Pettigrew et al. (1992) found that ethephon, an ethylene catalyst, decreased the height of cotton plants by 11% early after a pinhead-square application but, increased final plants height by 5%. Those findings suggest that blocking the perception of ethylene would have an impact on plant height. Thirteen days after pinhead-square (DAPHS), all of the six treatments that had received a pinhead square application of 1-MCP were taller than the UTC (Table 3). However statistical analysis over years failed to show separation between treatments.

Given the proposed role of ethylene in altering plant height of cotton (Pettigrew et al., 1992), node counts were taken in each plot to determine the effect of 1-MCP on the number of nodes per plant. If the number of nodes per plant were increased by 1-MCP, it could potentially result in additional fruiting sites. However as indicated by the statistical analysis in table 3, the total number of nodes was not influenced by 1-MCP, at thirteen DAPHS.

As previously discussed, ethylene can induce fruit shed in cotton (Morgan, 1969; Lipe and Morgan 1972; Guinn 1975). On the other hand, it has been proven that 1-MCP can block ethylene perception (Sisler and Serek, 1997; Sisler and Serek, 1999; Blankenship and Dole, 2002). Therefore, the percentage of squares shed was calculated

Table 3. Effect of 1-methylcyclopropene (1-MCP) on plant height, total number of nodes, percent square shed, relative chlorophyll content, and nodes above white flower (NAWF), thirteen days after pinhead-square.

	Plant height	Total nodes	Square shed	SPAD value	NAWF
				2005	2005
	cm	nodes plant^{-1}	%	value	nodes
Treatment†					
LPHS2	32.2a‡	10.54a	8.98a	40.1a	6.45bc
LPHS3	32.3a	10.55a	8.51a	39.4a	6.45bc
LEB2	31.4a	10.61a	15.63a	37.4a	6.55abc
LEB3	32.6a	10.55a	5.59a	37.0a	6.50dc
MPHS2	33.5a	10.60a	12.79a	38.7a	6.65abc
MPHS3	33.4a	10.75a	12.34a	37.8a	5.90d
MEB2	32.7a	10.49a	7.73a	37.1a	6.93ab
MEB3	34.3a	10.71a	7.25a	37.1a	7.05a
HPHS2	33.2a	10.69a	11.30a	39.3a	6.65abc
HPHS3	34.2a	10.84a	4.83a	39.2a	6.50bc
HEB2	33.7a	10.70a	12.68a	37.6a	6.70abc
HEB3	33.1a	10.63a	8.53a	38.0a	6.52bc
UTC	31.7a	10.66a	7.94a	38.9a	6.45bc
Surf	33.2a	10.88a	7.30a	38.9a	6.55abc

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

in each plot to determine the effect of 1-MCP on square retention. Thirteen DAPHS, percent square shed ranged from 4.8 % for the HPHS3 treatment to 15.6 % for the LEB2 treatment. However, statistical analysis resulted in no statistical separation among treatments. It is believed that the lack of statistical separation could, in part, be explained by variation between repetitions (coefficient of variation 84.8).

Research indicates that ethylene can induce chlorophyll degradation by stimulating the synthesis of the chlorophyllase enzyme (Kao and Yang, 1983). Conversely, a reduction in ethylene-mediated chlorophyll degradation was observed in the leaves of *Coriandrum sativum* treated with 1-MCP (Jiang et al., 2002). These findings prompted an evaluation of relative chlorophyll content with a SPAD meter to determine if application of 1-MCP would have an impact on chlorophyll degradation. The range of SPAD values, thirteen DAPHS, was 37.0 for the LEB3 treatment to 40.1 for the LPHS2 treatment. No significant differences among treatments were observed for relative chlorophyll content.

Nodes above white flower (NAWF) is a technique used to measure the growth status of a cotton crop in relation to physiological maturity. As a cotton plant matures, the growth of additional nodes slows and first position flowers occur closer to the apex of the plant (Bourland et al., 1992). At the point at which NAWF = 5, the crop is assumed to be at physiological maturity. NAWF was monitored after each 1-MCP application in 2005 to determine the effect of 1-MCP on physiological maturity. Thirteen DAPHS, NAWF ranged from 5.9 for the MPHS3 treatment to 7.0 for the MEB3 treatment. Of the

Table 4. Effect of 1-methylcyclopropene (1-MCP) on plant heights, total number of nodes, and percent square shed, one day prior to early bloom.

	Plant height	Total nodes		Square shed
		2005	2006	2006
	cm	nodes plant^{-1}		%
Treatment†				
LPHS2	53.43a‡	19.35a	13.53abc	3.53a
LPHS3	55.21a	19.05a	13.75ab	1.18a
LEB2	56.78a	20.15a	12.95bcd	5.08a
LEB3	54.67a	19.25a	14.00a	1.18a
MPHS2	56.84a	19.95a	12.68dc	3.15a
MPHS3	53.11a	18.90a	13.25abc	0.68a
MEB2	54.52a	20.15a	12.85cd	3.40a
MEB3	58.88a	20.20a	13.43abc	3.53a
HPHS2	54.31a	19.70a	13.30abc	2.30a
HPHS3	54.95a	19.35a	12.38d	1.43a
HEB2	55.58a	20.10a	13.25abc	2.35a
HEB3	55.92a	19.10a	12.83cd	4.33a
UTC	54.39a	19.75a	12.98bcd	3.68a
SURF	56.61a	20.00a	13.45abc	1.78a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

six treatments that had received a prior application of 1-MCP at PHS, the HPHS3 treatment was the only treatment significantly less than the UTC by 0.5 nodes.

One day prior to EB, an evaluation of plant growth and reproductive characteristics was again conducted (Table 4). At this measurement timing, all treatments that were initiated at PHS had received two applications of 1-MCP. When combined over years, plant heights ranged from 53.1 to 58.8 cm with no significant differences across treatments. Due to significant treatment x year interaction the total node counts could not be combined over years. Therefore, years were analyzed separately. In 2005, the number of nodes per plant was not influenced by 1-MCP. The following year significant differences from random variation were observed across treatments for number of nodes per plant. However, none of the six treatments receiving a PHS and fourteen DAPHS application of 1-MCP were significantly different for nodes per plant. Square shed was also measured one day prior to EB. All six treatments initiated at PHS had a numerically lower degree of square shed than the UTC. However, these data failed to separate statistically.

The fourth timing of plant growth and reproductive measurements were taken thirteen DAEB (Table 5). At this measurement timing treatments had received from one to three applications of 1-MCP. Analysis over years resulted in no significant differences between treatments for plant heights and total number of nodes per plant. In addition to plant growth, there were no significant differences observed between treatments for relative chlorophyll content or physiological maturity at thirteen DAEB. According to Guinn (1982), the rate of young fruit abscission increases from the beginning of the

Table 5. Effect of 1-methycyclopropene (1-MCP) relative chlorophyll content (SPAD), nodes above white flower (NAWF), plant heights, total number of nodes, and percent square shed, thirteen days after early bloom.

	SPAD value	NAWF	Plant height	Total nodes	Percent square shed
	2005	2005			2006
	——value——	——nodes——	——cm——	—nodes plant^{-1}—	——%——
Treatment†					
LPHS2	37.2a‡	5.45a	71.62a	16.93a	21.90a
LPHS3	36.5a	5.65a	70.84a	17.21a	23.88a
LEB2	35.1a	5.35a	77.24a	17.14a	15.78a
LEB3	34.5a	5.70a	73.55a	16.81a	28.95a
MPHS2	34.9a	5.35a	77.37a	17.81a	21.83a
MPHS3	35.3a	4.95a	73.21a	17.06a	18.20a
MEB2	36.8a	5.73a	74.62a	17.24a	16.60a
MEB3	33.6a	5.25a	78.83a	17.48a	19.03a
HPHS2	34.5a	5.50a	79.18a	17.31a	18.65a
HPHS3	36.6a	5.95a	73.39a	17.38a	26.28a
HEB2	35.1a	5.85a	76.59a	17.59a	14.98a
HEB3	36.3a	5.85a	73.05a	16.60a	19.58a
UTC	37.0a	5.90a	76.67a	17.51a	27.10a
SURF	34.3a	5.50a	77.69a	17.36a	21.10a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

growing season to the end. This was evident when square shed measurements were taken thirteen DAEB. The range for percent of total squares shed was 14.9 for the HEB2 treatment to 28.9 for the LEB3 treatment. In spite of the wide numerical range observed between treatments, the analysis failed to show separation between treatments. However, all treatments with the exception of the LEB3 treatment had a numerically lower percentage of total squares shed than the UTC.

The final in-field growth measurements were taken twenty-seven DAEB (Table 6). At this growth stage, all treatments had received at least two applications of 1-MCP. When combined over years, plant heights ranged from 76.0 cm for the LPHS2 treatment to 83.3 cm for the MPHS2 treatment with no statistical differences between treatments. Node counts were also pooled over years and the results indicate that 1-MCP did not affect the number of nodes per plant.

The final NAWF and SPAD measurements for 2005 and the first SPAD measurements for 2006 were also taken at twenty-seven DAEB. Although NAWF had a fairly wide range of 2.9 to 4.1, no significant differences were observed between treatments. Significant treatment x year interaction occurred for SPAD data; therefore, years could not be combined. In 2005, SPAD values ranged from 42.6 to 47.1 at twenty-seven DAEB with no significant differences. SPAD values were higher the following year with a range of 48.04 to 52.35. The higher SPAD values observed in 2006 could possibly be explained by differences in varietal characteristics. All treatments were numerically lower than the UTC but, no significant differences were observed.

At twenty-seven DAEB, percent square shed had a similar trend as the previous

Table 6. Effect of 1-methylcyclopropene (1-MCP) on nodes above white flower, plant heights, total number of nodes, relative chlorophyll content (SPAD), and percent square shed, twenty-seven days after early bloom.

	NAWF	Plant height	Total nodes	SPAD value	SPAD value	Square shed
	2005			2005	2006	2006
	——nodes——	———cm———	—nodes plant^{-1}—	——value——	——value——	———%———
Treatment†						
LPHS2	3.45a‡	76.02a	17.94a	45.3a‡	50.65a	21.90a
LPHS3	3.25a	76.86a	18.33a	47.1a	50.47a	23.88a
LEB2	3.35a	78.41a	18.35a	46.0a	49.04a	15.78a
LEB3	3.55a	77.90a	18.08a	42.6a	50.94a	28.95a
MPHS2	3.10a	83.37a	18.34a	46.0a	51.75a	21.83a
MPHS3	3.55a	79.39a	17.73a	45.2a	50.37a	18.20a
MEB2	4.13a	79.67a	17.69a	46.9a	52.33a	16.60a
MEB3	2.95a	83.34a	18.78a	45.8a	51.24a	19.03a
HPHS2	3.55a	80.33a	18.38a	46.3a	50.54a	18.65a
HPHS3	3.45a	79.28a	18.60a	46.2a	48.64a	26.28a
HEB2	3.35a	79.55a	18.30a	44.7a	51.41a	14.98a
HEB3	3.50a	77.78a	18.08a	47.0a	51.20a	19.58a
UTC	3.75a	80.17a	18.15a	45.1a	52.35a	27.10a
Surf	3.90a	82.45a	18.10a	43.2a	52.03a	21.10a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

square shed measurements (thirteen DAEB) with all 1-MCP treatments except the LEB treatment showing a numerically lower percentage of square shed than the UTC. However, no significant differences between treatments were observed. The results observed in this study for square retention were similar to those of Rethwisch et al. (2006) who examined the ethylene blocker Re Tain® ([S]-trans-2- Amino-4-(2-aminoethoxy)-3-butenoic acid hydrochloride) for fruit retention with no observed effect in cotton.

In addition to chlorophyll degradation, ethylene has also been shown to increase membrane leakiness (Suttle and Kende, 1980). Conversely, 1-MCP can delay membrane breakdown and decrease electrolytic leakage (Serek et al., 1995a; Jiang et al., 2002b). In 2006, variation of the technique described by Yang et al. (1996) was implemented to determine the effect of 1-MCP on electrolytic leakage. The results for these measurements are expressed as a percent of total cell solutes leaked into solution after a 1-hour treatment of 25° C and a 1-hour treatment of 40° C. Forty DAEB, the LPHS2 treatment had a significantly higher percentage of solutes leaked than the UTC after the 1-hour treatment of 25° C (Table 7). Moreover, all other 1-MCP treatments were numerically higher than the UTC. Similar results were observed at the 1-hour 40° C treatment. The LPHS2 and LPHS3 treatments were significantly higher for solute loss than the UTC and all other treatments were numerically higher.

The third and final SPAD measurements for 2006 were taken forty-five DAEB. The range for SPAD values was 45.8 to 50.8. The results of this measurement indicate that 1-MCP had no effect on relative chlorophyll content. However, SPAD values were

Table 7. Effect of 1-methylcyclopropene (1-MCP) on relative chlorophyll content (SPAD) and electrolytic leakage, forty-five days after early bloom, 2006.

	SPAD value	percent total solutes†	percent total solutes‡
	———value———	———%———	———%———
Treatment§			
LPHS2	47.23a¶	12.60a	20.93a
LPHS3	50.82a	11.20ab	18.48ab
LEB2	47.35a	10.40ab	15.48bc
LEB3	47.89a	9.50bc	14.73bc
MPHS2	49.16a	11.20ab	16.40bc
MPHS3	45.82a	11.30ab	17.23abc
MEB2	49.16a	10.60ab	15.35bc
MEB3	49.43a	11.15ab	16.05bc
HPHS2	46.96a	10.30abc	15.23bc
HPHS3	50.59a	9.90bc	14.55bc
HEB2	46.98a	10.98ab	17.18abc
HEB3	50.74a	7.85c	13.73c
UTC	50.46a	9.15bc	13.73c
Surf	50.77a	9.78bc	14.55bc

†Percent of total solutes leaked at 1 hour 25°C.
‡Percent of total solutes leaked at 1 hour 40°C.
§ Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha^{-1} at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
¶Values within a column followed by the same letter are not different at the 0.10 probability level using Fischer's protected LSD.

higher than the previous measurements (twenty-seven DAEB) suggesting that senescence had not been induced.

Box-mapping

End of season box-mapping was utilized in this study to obtain a better understanding of yield responses. Bolls were separated by node and fruiting position to determine yield distribution across plants. The technique utilized in this study was a variation of that described by Jenkins and McCarty (1995). In 2005, six representative plants were removed from each plot prior to harvest for box-mapping. To obtain a better representation of yield, 10 plants were extracted from each plot the following year. Consequently, these data could not be combined over years for statistical analysis.

In 2005, 1-MCP had no effect on the number, percent of total bolls, or weight of bolls located on nodes 3 through 5 (Table 8). The average number of bolls per plant located on the third through fifth node was less than 0.33 for all treatments. Therefore, bolls from this region accounted for a minute portion of total yield. Jenkins et al. (1990) showed that the first sympodial branch usually occurs at nodes 5 through 7 and branches located below the fifth node are usually monopodial. The findings from my study suggest that the majority of bolls collected from nodes 3 through 5 were located on monopodial branches. Results for yield components located on nodes 3 through 5 were similar in 2006 with no significant differences between treatments (Table 9).

A larger number of bolls that correspond to yield were located on nodes 6 through 10 than at other nodal positions (Tables 10 and 11). In 2005 and 2006 the range for total number of bolls per plant at nodes 6 through 10 was 1.7 to 2.6 and 3.6 to 4.6,

Table 8. Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 3 through 5, 2005.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	0.08a‡	0.88a	0.39a	2.33a
LPHS3	0.00a	0.00a	0.00a	0.00a
LEB2	0.00a	1.06a	0.18a	1.05a
LEB3	0.06a	0.78a	0.24a	1.43a
MPHS2	0.17a	1.96a	0.50a	1.51a
MPHS3	0.08a	1.00a	0.17a	1.03a
MEB2	0.06a	0.73a	0.06a	0.33a
MEB3	0.00a	0.00a	0.00a	0.00a
HPHS2	0.06a	0.54a	0.07a	0.40a
HPHS3	0.00a	0.00a	0.00a	0.00a
HEB2	0.17a	2.86a	0.09a	0.26a
HEB3	0.17a	1.85a	0.79a	2.38a
UTC	0.25a	2.94a	1.11a	2.23a
Surf	0.33a	3.62a	1.32a	5.28a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 9. Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 3 through 5, 2006.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	0.33a‡	3.90	2.36a	6.33a
LPHS3	0.37a	4.64	2.28a	6.27a
LEB2	0.33a	5.15	1.40a	4.13a
LEB3	0.57a	6.93	2.33a	4.07a
MPHS2	0.33a	3.89	1.23a	3.01a
MPHS3	0.45a	2.93	1.23a	4.08a
MEB2	0.50a	7.49	2.94a	5.61a
MEB3	0.35a	4.60	1.47a	3.86a
HPHS2	0.30a	3.84	1.08a	2.37a
HPHS3	0.37a	4.87	1.44a	3.35a
HEB2	0.33a	5.22	1.81a	5.08a
HEB3	0.40a	4.81	1.89a	4.64a
UTC	0.33a	3.86	1.41a	4.20a
Surf	0.33a	4.51	1.53a	5.07a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 10. Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 6 through 10, 2005.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	1.92a‡	22.06a	7.32a	3.94a
LPHS3	2.00a	30.45a	7.62a	3.87a
LEB2	2.08a	24.20a	8.37a	4.00a
LEB3	1.22a	20.20a	4.16a	3.34a
MPHS2	2.17a	26.41a	9.09a	4.11a
MPHS3	1.92a	24.71a	7.07a	3.71a
MEB2	1.72a	25.27a	6.26a	3.87a
MEB3	2.00a	26.88a	6.34a	3.12a
HPHS2	2.50a	25.25a	11.51a	5.00a
HPHS3	1.83a	19.59a	7.83a	4.25a
HEB2	2.67a	32.29a	4.75a	3.64a
HEB3	2.25a	26.51a	8.83a	3.89a
UTC	1.83a	23.72a	7.82a	4.27a
Surf	2.42a	26.50a	10.12a	4.08a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 11. Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 6 through 10, 2006.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	4.67a‡	54.98a	15.15a	3.23a
LPHS3	4.20a	51.77a	17.90a	4.30a
LEB2	4.00a	57.96a	16.88a	4.24a
LEB3	4.13a	50.90a	18.13a	4.40a
MPHS2	4.38a	51.25a	19.84a	4.55a
MPHS3	3.98a	52.29a	17.54a	4.41a
MEB2	4.03a	51.05a	18.41a	4.46a
MEB3	3.60a	51.25a	17.00a	4.74a
HPHS2	3.97a	50.01a	17.56a	4.39a
HPHS3	3.90a	52.94a	16.98a	4.21a
HEB2	3.63a	51.62a	17.55a	4.89a
HEB3	4.85a	56.06a	20.68a	4.24a
UTC	4.27a	47.76a	19.21a	4.45a
Surf	4.43a	55.71a	15.01	3.45a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

respectively. These numbers correspond to percentage values of 19.5 to 32.2 and 47.7 to 56.0, respectively. No significant differences were found among treatments for either year. However, bolls in the node 6 through ten node range of the plant accounted for a larger component of final yield in 2006.

In 2005, the majority of seed cotton was located on nodes 11 through 15 (Table 12). The range for number of bolls per plant and percentage of total bolls in this region was 1.8 to 4.6 and 39.7 to 56.1%, respectively. No significant differences were observed across treatments for number of bolls, percentage of total bolls, total boll weight, or average boll weight for nodes 6 through 10. In 2006, approximately 1/3 of total bolls were located on nodes 6 through 10 with no significant differences across treatments (Table 13). In addition, 1-MCP had no effect on the number of bolls, percent of total bolls, and total boll weight from nodes 16 through 20 (Tables 14 and 15).

Fruit distribution by position plays a major role in final yield. Generally, first position bolls are the largest and subsequently contribute the most to lint yield (Jenkins and McCarty 1995). Therefore, it is desirable to retain bolls in this position. The results from box-mapping indicate that 1-MCP did not affect the number, percentage of total bolls, total boll weight per plant, or average boll weight of first position bolls (Tables 16 and 17). In addition, 1-MCP did not affect the above parameters for bolls in the second position (Tables 18 and 19) or third position (Tables 20 and 21).

Monopodia usually occur at the lower part of the plant below the fruiting branches. Like fruiting branches, monopodia can also produce harvestable bolls. However, this process is slower and inefficient (Deterling, 1982). In 2005, no bolls

Table 12. Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 11 through 15, 2005.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	4.25a‡	49.77a	15.08a	3.57a
LPHS3	3.08a	46.80a	11.14a	3.62a
LEB2	4.00a	46.45a	14.20a	3.51a
LEB3	3.50a	56.10a	11.66a	3.31a
MPHS2	4.00a	49.06a	12.51a	3.13a
MPHS3	4.25a	55.76a	16.03a	3.78a
MEB2	3.22a	45.13a	11.63a	3.58a
MEB3	3.67a	51.01a	12.79a	3.47a
HPHS2	4.33a	42.61a	14.96a	3.47a
HPHS3	1.83a	50.79a	15.53a	3.29a
HEB2	4.75a	39.70a	13.55a	4.15a
HEB3	3.92a	45.83a	14.21a	3.57a
UTC	4.08a	53.06a	15.53a	3.79a
Surf	4.67a	51.52a	18.00a	3.83a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 13. Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 11 through 15, 2006.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	2.80a‡	32.93a	7.38a	2.69a
LPHS3	2.67a	31.94a	9.98a	3.68a
LEB2	2.10a	29.51a	9.10a	4.48a
LEB3	2.63a	30.90a	11.06a	4.03a
MPHS2	3.13a	35.01a	11.82a	3.79a
MPHS3	2.55a	32.75a	9.27a	3.52a
MEB2	2.50a	31.49a	10.59a	4.08a
MEB3	2.78a	37.28a	10.68a	3.67a
HPHS2	2.70a	33.25a	11.09a	4.09a
HPHS3	2.93a	31.75a	11.81a	3.97a
HEB2	2.40a	31.92a	9.24a	3.68a
HEB3	2.45a	26.87a	9.62a	3.86a
UTC	3.27a	34.82a	13.92a	4.24a
Surf	2.75a	32.47a	10.41a	3.70a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 14. Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 16 through 20, 2005.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	1.42a‡	16.80a	5.76a	4.08a
LPHS3	1.33a	20.22a	4.01a	2.98a
LEB2	2.33a	27.39a	8.78a	3.76a
LEB3	1.22a	19.65a	3.55a	2.95a
MPHS2	1.00a	12.60a	3.23a	3.22a
MPHS3	0.92a	11.76a	3.05a	3.23a
MEB2	1.61a	22.19a	5.87a	3.64a
MEB3	1.50a	20.89a	5.53a	3.78a
HPHS2	1.95a	19.34a	7.40a	3.95a
HPHS3	2.33a	24.07a	8.74a	3.77a
HEB2	1.42a	15.56a	4.49a	3.00a
HEB3	1.25a	15.05a	4.62a	3.67a
UTC	1.50a	20.28a	5.68a	3.80a
Surf	1.00a	11.02a	2.81a	2.81a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 15. Effect of 1-methylcyclopropene (1-MCP) on number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant for sympodial branches 16 through 20, 2006.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	0.23a‡	2.68a	0.81a	3.89a
LPHS3	0.17a	1.90a	0.44a	1.82a
LEB2	0.27a	3.91a	0.75a	2.77a
LEB3	0.20a	1.43a	0.74a	1.24a
MPHS2	0.63a	6.67a	2.05a	3.25a
MPHS3	0.50a	5.72a	1.52a	2.34a
MEB2	0.10a	1.21a	0.49a	3.68a
MEB3	0.43a	4.97a	1.19a	2.74a
HPHS2	0.40a	4.80a	1.37a	2.71a
HPHS3	0.60a	5.47a	1.70a	1.99a
HEB2	0.37a	3.74a	1.34a	1.22a
HEB3	0.43a	3.74a	1.32a	1.72a
UTC	0.77a	7.60a	2.74a	3.15a
Surf	0.45a	4.27a	1.36a	1.59a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 16. Effect of 1-methylcyclopropene (1-MCP) on first position number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant, 2005.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	4.42a‡	51.32a	17.20a	3.90a
LPHS3	4.08a	62.08a	15.10a	3.71a
LEB2	5.67a	66.53a	22.43a	3.96a
LEB3	4.39a	69.98a	14.99a	3.39a
MPHS2	4.08a	50.04a	15.73a	3.85a
MPHS3	4.67a	61.33a	18.55a	3.98a
MEB2	4.78a	68.05a	18.31a	3.79a
MEB3	4.67a	64.58a	16.44a	3.52a
HPHS2	5.72a	57.01a	22.69a	3.97a
HPHS3	4.75a	51.43a	18.94a	3.98a
HEB2	4.33a	54.15a	16.68a	3.87a
HEB3	4.67a	54.86a	18.93a	4.03a
UTC	4.58a	60.14a	26.14a	5.81a
Surf	4.92a	53.99a	18.56a	3.77a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 17. Effect of 1-methylcyclopropene (1-MCP) on first position number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant, 2006.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	5.97a‡	70.23a	18.33a	3.10a
LPHS3	5.93a	72.48a	25.29a	4.23a
LEB2	5.80a	84.33a	25.64a	4.45a
LEB3	6.03a	75.01a	26.26a	4.28a
MPHS2	6.68a	74.48a	28.36a	4.25a
MPHS3	6.10a	74.48a	25.16a	4.17a
MEB2	5.53a	74.33a	25.98a	4.65a
MEB3	5.93a	82.43a	25.33a	4.23a
HPHS2	5.50a	69.06a	24.24a	4.41a
HPHS3	6.00a	78.09a	25.37a	4.14a
HEB2	5.57a	78.67a	25.69a	4.59a
HEB3	6.40a	72.90a	27.74a	4.32a
UTC	6.33a	69.68a	28.83a	4.52a
Surf	6.40a	79.66a	22.77a	3.62a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 18. Effect of 1-methylcyclopropene (1-MCP) on second position number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant, 2005.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	2.25a‡	26.20a	7.68a	3.45a
LPHS3	1.58a	24.07a	5.22a	3.29a
LEB2	2.00a	23.14a	6.33a	3.03a
LEB3	1.39a	23.16a	3.67a	2.63a
MPHS2	2.17a	26.66a	6.26a	2.86a
MPHS3	1.67a	20.95a	4.74a	2.66a
MEB2	1.28a	17.16a	4.05a	3.27a
MEB3	2.25a	30.94a	7.33a	3.24a
HPHS2	2.22a	21.93a	8.31a	3.74a
HPHS3	3.17a	33.44a	10.52a	3.36a
HEB2	2.25a	25.15a	8.18a	3.36a
HEB3	1.75a	20.37a	5.27a	2.93a
UTC	2.25a	28.38a	7.85a	3.41a
Surf	2.08a	23.03a	8.66a	4.95a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 19. Effect of 1-methylcyclopropene (1-MCP) on second position number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant, 2006.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	1.77a‡	20.71a	6.39a	3.63a
LPHS3	1.47a	17.78a	5.31a	3.59a
LEB2	0.87a	11.80a	2.34a	3.14a
LEB3	1.30a	13.72a	5.39a	4.30a
MPHS2	1.65a	16.83a	6.22a	4.7a
MPHS3	1.28a	17.81a	4.05a	3.17a
MEB2	1.40a	16.60a	5.86a	3.93a
MEB3	1.20a	15.19a	4.86a	4.14a
HPHS2	1.73a	21.72a	6.09a	3.54a
HPHS3	1.43a	13.50a	5.48a	3.31a
HEB2	1.13a	13.50a	4.03a	3.66a
HEB3	1.55a	16.81a	5.10a	3.09a
UTC	2.03a	21.61a	7.44a	3.64a
Surf	1.40a	15.81a	5.08a	3.57a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 20. Effect of 1-methylcyclopropene (1-MCP) on third position number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant, 2005.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	1.00a‡	12.00a	3.66a	3.48a
LPHS3	0.75a	11.31a	2.46a	3.46a
LEB2	0.83a	9.44a	2.76a	3.24a
LEB3	0.22a	3.6a	0.95a	4.13a
MPHS2	1.08a	13.33a	3.36a	3.11a
MPHS3	0.83a	10.95a	3.03a	3.64a
MEB2	0.56a	8.12a	1.45a	2.45a
MEB3	0.25a	3.26a	0.89a	1.78a
HPHS2	0.89a	8.80a	2.93a	3.10a
HPHS3	1.08a	10.34a	2.90a	3.13a
HEB2	1.08a	12.53a	3.22a	2.94a
HEB3	1.17a	14.00a	4.26a	3.96a
UTC	0.83a	11.50a	2.76a	3.54a
Surf	1.42a	15.63a	5.03a	3.57a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 21. Effect of 1-methylcyclopropene (1-MCP) on third position number of bolls, percent of total bolls, total boll weight, and mean boll weight per plant, 2006.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	——boll plant $^{-1}$——	———%———	———g———	———g———
Treatment†				
LPHS2	0.30a‡	3.54a	0.97a	3.09a
LPHS3	0.00a	0.00a	0.00a	0.00a
LEB2	0.03a	0.38a	0.17a	1.63a
LEB3	0.20a	1.43a	0.62a	1.04a
MPHS2	0.13a	1.32a	0.34a	2.03a
MPHS3	0.10a	1.40a	0.38a	0.96a
MEB2	0.20a	2.15a	0.58a	1.91a
MEB3	0.03a	1.20a	0.14a	1.91a
HPHS2	0.13a	0.34a	0.47a	1.44a
HPHS3	0.37a	2.66a	1.08a	0.98a
HEB2	0.03a	0.34a	0.23a	2.33a
HEB3	0.18a	1.88a	0.68a	3.55a
UTC	0.27a	2.74a	1.00a	3.67a
Surf	0.15a	1.49a	0.45a	1.50a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

were found on monopodial branches for the UTC (Table 22). Because there were no monopodial bolls on these plants, all 1-MCP treatments had a higher number of bolls, percentage of total bolls, total boll weight, and mean boll weight of monopodial bolls per plant. However, statistical analysis failed to show separation between treatments. Additionally, there were no significant differences for monopodial bolls the following year (Table 23).

The final box-mapping parameters assessed plant growth and yield on a whole plant basis. In both years of this study no significant separation was observed between treatments for plant height, total number of number of nodes per plant, height to node ratio, total number of bolls per plant, or total boll weight per plant (Table 24 and 25).

Yield

Due to significant treatment x year interaction, yields and percent gin turnout could not be pooled over years for statistical analysis. In 2005, seed cotton yield ranged from 3,253 to 3,721 kg ha^{-1} (Table 26). Six 1-MCP treatments; LEB3, MPHS2, MPHS3, MEB3, HPHS2, and HEB3 significantly enhanced seed cotton yield above the UTC. Additionally, all other 1-MCP treatments were numerically higher than the UTC. No significant differences were observed for gin-turnout. Therefore, the differences in seed cotton yield were also examined for lint yield. The range across treatments for lint yield was 1,388 for the UTC to 1,595 kg ha^{-1} for the MPHS3 treatment. As seen with seed cotton yield the LEB3, MPHS2, MPHS3, MEB3, HPHS2, and HEB3 treatments were significantly higher than the UTC and all other 1-MCP treatments were numerically higher suggesting an increase in boll

Table 22. Effect of 1-methylcyclopropene (1-MCP) on total number of bolls, percent of total bolls, total boll weight, mean boll weight per plant on monopodial branches, 2005.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	—boll plant^{-1}—	———%———	——————g——————	
Treatment†				
LPHS2	0.92a‡	9.97a	4.01a	4.26a
LPHS3	0.17a	2.53a	0.66a	3.98a
LEB2	0.08a	0.89a	0.75a	4.48a
LEB3	0.22a	3.28a	0.69a	1.97a
MPHS2	0.83a	12.26a	2.68a	2.65a
MPHS3	0.50a	12.26a	1.92a	3.67a
MEB2	0.56a	6.67a	1.67a	2.07a
MEB3	0.08a	8.16a	0.21a	1.23a
HPHS2	1.31a	10.49a	3.23a	1.49a
HPHS3	0.50a	4.80a	2.33a	4.46a
HEB2	0.75a	8.16a	3.31a	3.33a
HEB3	0.92a	0.76a	5.58a	5.97a
UTC	0.00a	0.00a	0.00a	0.00a
Surf	0.67a	7.35a	2.16a	3.23a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 23. Effect of 1-methylcyclopropene (1-MCP) on total number of bolls, percent of total bolls, total boll weight, mean boll weight per plant on monpodial branches, 2006.

	Total bolls	Percent total bolls	Total boll weight	Mean boll weight
	—boll plant^{-1}—	———%———	——————g——————	
Treatment†				
LPHS2	0.47a‡	5.52a	1.86a	4.08a
LPHS3	0.80a	9.75a	3.29a	4.15a
LEB2	0.23a	3.48a	1.00a	4.07a
LEB3	1.10a	9.84a	4.13a	3.81a
MPHS2	0.33a	3.19a	1.43a	2.44a
MPHS3	0.50a	6.30a	1.35a	3.23a
MEB2	0.60a	6.92a	2.54a	7.24a
MEB3	0.18a	2.10a	0.55a	2.27a
HPHS2	0.80a	8.02a	3.43a	3.81a
HPHS3	0.47a	4.98a	2.29a	4.92a
HEB2	0.47a	7.49a	1.96a	4.45a
HEB3	0.80a	8.41a	3.09a	3.48a
UTC	0.57a	5.97a	2.38a	4.49a
Surf	0.30a	3.04a	1.36a	2.31a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 24. Effect of 1-methylcyclopropene (1-MCP) on plant height, total nodes, height to node ratio, total number of bolls and total boll weight per plant, 2005.

	Plant height	Total nodes	Height/Node ratio	Total bolls	Total boll weight
	———cm———	——nodes plant^{-1}——		——boll plant $^{-1}$——	———g———
Treatment†					
LPHS2	80.33a‡	20.42a	3.93a	8.58a	32.55a
LPHS3	87.75a	19.83a	4.04a	6.58a	23.43a
LEB2	87.76a	21.75a	4.04a	8.58a	32.26a
LEB3	90.44a	20.83a	4.44a	6.22a	20.30a
MPHS2	87.33a	19.68a	4.45a	8.17a	28.02a
MPHS3	87.56a	20.33a	4.28a	7.67a	28.23a
MEB2	87.56a	21.06a	4.16a	7.17a	25.48a
MEB3	94.00a	21.5a	4.37a	7.25a	24.86a
HPHS2	85.67a	19.75a	4.34a	10.14a	36.53a
HPHS3	89.83a	22.25a	4.04a	9.50a	34.68a
HEB2	79.92a	20.17a	3.96a	8.42a	31.38a
HEB3	81.42a	20.17a	3.89a	8.50a	34.03a
UTC	89.58a	20.17a	4.44a	7.67a	36.78a
Surf	88.33a	20.75a	4.25a	9.08a	34.07a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 25. Effect of 1-methylcyclopropene (1-MCP) on plant height, total number of nodes, height to node ratio, total number of bolls and total boll weight per plant, 2006.

	Plant height	Total nodes	Height/Node ratio	Total bolls	Total boll weight
	———cm———	——nodes plant^{-1}——		——boll plant $^{-1}$——	———g———
Treatment†					
LPHS2	63.70a‡	17.47a	3.65a	8.50a	27.55a
LPHS3	66.67a	17.60a	3.78a	8.20a	33.88a
LEB2	67.03a	17.23a	3.91a	6.93a	29.13a
LEB3	63.53a	17.43a	3.65a	8.63a	36.39a
MPHS2	75.70a	17.83a	4.23a	8.78a	36.36a
MPHS3	76.10a	17.93a	4.20a	7.73a	30.90a
MEB2	68.70a	17.90a	3.84a	7.73a	34.95a
MEB3	68.58a	17.65a	3.85a	7.33a	30.85a
HPHS2	74.73a	17.68a	4.23a	8.17a	34.22a
HPHS3	80.05a	17.66a	4.33a	8.27a	34.21a
HEB2	73.19a	17.63a	4.13a	7.20a	31.91a
HEB3	68.30a	17.65a	3.91a	8.93a	36.61a
UTC	73.93a	17.80a	4.13a	9.20a	39.65a
Surf	70.70a	17.48a	4.03a	8.25a	29.65a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 26. Effect of 1-methylcyclopropene (1-MCP) on seedcotton yield, gin turnout, and lint yield, 2005.

	Seed cotton	Lint	Lint
	—— kg ha^{-1}——	——%——	—— kg ha^{-1}——
Treatment†			
LPHS2	2915d‡	43.00a	1253de
LPHS3	2954d	42.75a	1260de
LEB2	3102a-d	42.75a	1333a-e
LEB3	3256abc	41.75a	1361a-d
MPHS2	3289ab	42.25a	1400ab
MPHS3	3322a	43.00a	1424a
MEB2	3058bcd	42.00a	1273cde
MEB3	3311a	43.00a	1420ab
HPHS2	3251abc	42.50a	1380abc
HPHS3	3042cd	43.00a	1312b-e
HEB2	3025cd	42.25a	1277cde
HEB3	3229abc	44.00a	1417ab
UTC	2904d	42.75a	1239e
Surf	3091a-d	43.25a	1332a-e

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.

‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

number, boll size, seed number, or seed size. However, the yield enhancement observed in 2005 was not explained by the evaluation of yield components conducted through box-mapping (no significant differences between treatments for boll number or boll size per plant). Furthermore, there was no definite relationship between yield and rate, timing of treatment initiation, or number of applications.

In 2006, yields were lower (Table 27). The ranges for seed cotton and lint yield were 2241 to 2,486 kg ha^{-1} and 986 to 1,097 kg ha^{-1} respectively. Application of 1-MCP did not influence seed cotton yield, gin-turnout, or lint yield in 2006.

High volume instrument testing (HVI) was utilized in this study to determine lint quality characteristics: micronaire, length, uniformity, strength, reflectance (Rd), and degree of yellowness (+b). There were no significant differences for lint quality parameters between treatments for 2005 or 2006 (Table 28 and 29). In order to maximize profits, it is desirable to meet certain classification of fiber in order to obtain a premium price for lint (USDA, 1993). In both years of this study fiber qualities were within acceptable ranges for this production area.

Table 27. Effect of 1-methylcyclopropene (1-MCP) on seed cotton yield, gin turnout, and lint yield, 2006.

	Seed cotton	Lint	Lint
	—— kg ha^{-1}——	——%——	—— kg ha^{-1}——
Treatment†			
LPHS2	2062a‡	44.01a	907a
LPHS3	2219a	43.94a	975a
LEB2	2068a	44.18a	914a
LEB3	2091a	44.39a	928a
MPHS2	2147a	43.64a	937a
MPHS3	2001a	43.98a	880a
MEB2	2147a	43.82a	941a
MEB3	2159a	43.85a	947a
HPHS2	2051a	44.20a	906a
HPHS3	2209a	43.72a	966a
HEB2	2051a	43.92a	900a
HEB3	2216a	43.98a	974a
UTC	2203a	43.96a	968a
Surf	2217a	44.17a	979a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.

‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 28. Effect of 1-methycyclopropene (1-MCP) on lint quality parameters, 2005.

	Micronaire	Length	Uniformity	Strength	Rd	+b
		—cm—		—g tex^{-1}—		
Treatment†						
LPHS2	4.83a‡	1.11a	82.78a	29.68a	65.65a	9.48a
LPHS3	4.80a	1.11a	82.50a	29.58a	66.58a	9.05a
LEB2	4.70a	1.10a	82.38a	29.23a	66.28a	9.13a
LEB3	4.58a	1.10a	81.93a	28.50a	64.55a	9.10a
MPHS2	4.58a	1.10a	82.55a	29.63a	69.95a	8.95a
MPHS3	4.56a	1.11a	82.13a	30.45a	64.25a	8.90a
MEB2	4.60a	1.11a	82.30a	29.50a	69.93a	9.10a
MEB3	4.63a	1.10a	82.28a	29.10a	65.50a	8.83a
HPHS2	4.70a	1.11a	82.40a	30.35a	65.23a	9.18a
HPHS3	4.58a	1.11a	82.50a	30.00a	66.20a	9.13a
HEB2	4.58a	1.10a	82.73a	29.78a	64.15a	8.70a
HEB3	4.60a	1.10a	83.10a	28.88a	64.90a	9.13a
UTC	4.50a	1.10a	82.23a	30.03a	67.30a	9.18a
Surf	4.89a	1.10a	82.70a	28.88a	63.75a	8.95a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

Table 29. Effect of 1-methycyclopropene (1-MCP) on lint quality parameters, 2006.

	Micronaire	Length	Uniformity	Strength	Rd	+b
		—cm—		—g tex^{-1}—		
Treatment†						
LPHS2	4.85a‡	1.03a	81.70a	30.15a	68.53a	9.13a
LPHS3	5.03a	1.03a	81.90a	29.53a	69.6a	9.30a
LEB2	4.90a	1.03a	81.25a	28.33a	68.33a	9.28a
LEB3	4.93a	1.05a	81.60a	29.10a	64.43a	9.00a
MPHS2	4.93a	1.04a	82.60a	30.18a	69.30a	8.98a
MPHS3	4.98a	1.05a	81.58a	29.93a	67.70a	9.28a
MEB2	4.85a	1.06a	82.50a	29.73a	68.58a	9.18a
MEB3	5.10a	1.03a	81.50a	28.28a	68.63a	9.33a
HPHS2	4.93a	1.07a	82.78a	30.45a	69.88a	9.20a
HPHS3	4.88a	1.08a	81.53a	29.20a	70.23a	9.03a
HEB2	4.95a	1.05a	82.28a	29.88a	69.93a	9.13a
HEB3	5.00a	1.04a	82.20a	29.23a	69.00a	9.10a
UTC	5.03a	1.04a	81.48a	29.90a	66.98a	9.00a
Surf	5.00a	1.03a	81.25a	27.18a	68.13a	8.83a

† Abbreviations: L, 1-MCP at 250 g ha^{-1}; M, 1-MCP at 500 g ha^{-1}; H, 1-MCP at 1250 g ha^{-1}; PHS, treatment initiated at pinhead-square; EB, treatment initiated at EB; 2, two applications in fourteen-day increments; 3, three applications in fourteen-day increments; UTC, untreated control; SURF, surfactant applied at 0.09 L ha $^{-1}$ at early bloom, fourteen days after early bloom, and twenty-eight days after early bloom.
‡ Values within a column followed by the same letter are not different at the 0.05 probability level using Fischer's protected LSD.

CONCLUSIONS

In cotton, fruit abscission is a common physiological response to stress. Research indicates that this abscission is primarily through the action of ethylene. The plant growth regulator1-methylcyclopropene (1-MCP) is a gaseous compound with a high affinity for ethylene receptors. When bound to ethylene receptors, 1-MCP blocks the perception of these receptors to ethylene. Therefore, ethylene cannot generate a physiological response. To date more than one hundred studies have been conducted with 1-MCP in a variety of horticultural crops. Effects have been reported on abscission, chlorophyll degradation, electrolytic leakage, and many other physiological responses. Currently, 1-MCP is widely used in the post-harvest of many fruit, vegetable, and flowering crops to counter the effects of ethylene. To date there is no information on the use of 1-MCP in cotton. This study was designed to test the rate and timing of foliar spray applications of 1-MCP to determine its effect on cotton growth and yield.

In the first year of this study yield was significantly increased by six of the twelve 1-MCP treatments that comprised this study. However, no significant differences were observed for number of bolls per plant, average boll weight, or gin turnout that might explain the increase in yield. Therefore, the yield enhancement observed in the first year of this study can not be attributed to any single factor. In the following year 1-MCP did not influence yields. Moreover, 1-MCP did not have a beneficial effect on plant growth. Contrary to the hypothesis that 1-MCP should delay senescence, electrolytic leakage was significantly increased by two 1-MCP treatments suggesting that 1-MCP could possibly promote earliness.

The results of this study suggest that the 1-MCP compound used in this study did increase lint yield in one of the two years of the study but, had little effect on other cotton growth and yield parameters. However, 1-MCP has proven to be a useful tool in the horticulture industry and therefore, it is believed that 1-MCP may have potential as a plant growth regulator in agronomic crops. Further studies should be conducted with 1-MCP to investigate formulation, uptake, and delivery with foliar applications. Due to the volatility of the compound, the duration of exposure could have been inadequate to achieve protection. Previous research suggests that durations of 12 to 24 hours are needed for full protection. It is believed that a slow release formulation could be beneficial.

REFERENCES

Abdi, N., W.B. McGlasson, P. Holford, M. Williams, and Y. Mizrahik. 1998. Responses of climacteric and suppressed-climacteric plums to treatment with propylene and 1-methylcyclopropene. Postharvest Biol. Technol. 14:29–39.

Abeles, F. B. 1968. Role of RNA and protein synthesis in abscission. Plant Physiol. 43:1577-1586.

Abeles, F. B. 1969. Abscission: Role of cellulase. Plant Physiol. 44: 447-452.

Abeles, F.B. 1973. Ethylene in Plant Biology. Academic Press, New York, NY.

Adams, D.O. and S. F. Yang. 1979. Ethylene biosynthesis: Identification of 1-aminocyclopropane-1-carboxylic acid as an intermediate in the conversion of methionine to ethylene. Proc. Natl. Acad. Sci. USA. 76:170–74.

Apelbaum, A. and S.F. Yang. 1981. Biosynthesis of stress ethylene induced by water deficit. Plant Physiol. 68: 594-596.

Baritelle, A.L., G.M. Hyde, J.K. Fellman, and J. Varith. 2001. Using 1-MCP to inhibit the influence of ripening on impact properties of pear and apple tissue. Postharvest Biol. Technol. 23:153–160.

Beltrano, J., M.G. Ronco, and E.R. Montaldi. 1999. Drought stress syndrome in wheat is provoked by ethylene evolution imbalance and reversed by rewatering, aminoethoxyvinylglycine, or sodium benzoate. J. Plant Growth Regul. 18:59–64.

Blankenship, S.M. and J.M. Dole. 2002. 1-Methylcyclopropene: A review. Postharvest Biol. Technol. 28:1-25.

Bleecker, A.B. and S.E. Patterson. 1997. Last exit: Senescence, abscission, and meristem arrest in arabidopsis. The Plant Cell. 9:1169-1179.

Bleecker, A.B. 1999. Ethylene perception and signaling: An evolutionary perspective. Trends in Plant Science. 7:269-279.

Bleecker A.B. and H. Kende. 2000. Ethylene: A gaseous signal molecule. Cell Dev. Biol. 16:1-18.

Bourland, F.M., D.M. Oosterhuis, and N.P. Tugwell. 1992. Concept of monitoring the growth and development of cotton plants using main-stem node counts. J. Prod. Agric. 5 (4): 532-538.

Burg, S.P. 1968. Ethylene, plant senescence and abscission. Plant Physiol. 43: 1503-1511.

Chen, Y.F., M.D. Randlett, J.L. Findall, and G.E. Shaller. 2002. Localization of the ethylene receptor ETR1 to the endoplasmic reticulum. J. Biol. Chem. 2002. 277:19861-19866.

Clark, K.L., P.B. Larsen, X. Wang, C. Chang. 1998. Association of the *Arabidopsis* CTR1 Raf-like kinase with the ETR1 and ERS ethylene receptors. Proc. Natl. Acad. Sci. USA 95:5401-6

Cochran, M.J., N.P. Tugwell, F.M. Bourland, D.M. Oosterhuis, and D.M. Danfourth. 1998: COTMAN III Expert System – Version 5.0, 2006. University of Arkansas.

Cooper, W.C., G. K. Rasmussen, and E. S. Waldon. 1969. Ethylene evolution stimulated by chilling in citrus and persea sp. Plant Physiol. 44:1194-1196.

Crocker, W., A.E. Hitchcock, and P.W. Zimmerman. 1935. Similarities in the effects of ethylene and the plant auxins. Contrib. Boyce Thompson Inst. 7:231-248.

DeEll, J.R., D.P. Murr, M.D. Porteous, and H.P.V. Rupasinghe. 2002. Influence of temperature and duration of 1-methylcyclopropene (1-MCP) treatment on apple quality. Postharvest Biol. Technol. 24:349–353.

Deterling, D. and K. M. El-Zik. 1982. How a cotton plant grows. Bulletin, Progressive Farmer. Progressive Farmer Inc. Birmingham, AL.

De Wild, H.P.J., E.J. Woltering, H.W. Peppelenbos. 1999. Carbon dioxide and 1-MCP inhibit ethylene production and respiration of pear fruit by different mechanisms. J. Exp. Bot. 50:837–844.

Dong, L., W. Zhou-Hong, L. Sonego, A. Lers, and S. Lurie. 2001. Ripening of 'Red Rosa' plums: Effect of ethylene and 1-methylcyclopropene. Aust. J. Plant Physiol. 28:1039–1045.

Eaton, F.M., and N.E. Rigler. 1945. Effect of light intensity, nitrogen supply, and fruiting on carbohydrate utilization by the cotton plant. Plant Physiol. 20:380-411.

Fan, X., J.P. Mattheis. and S.M. Blankenship. 1999. Development of apple superficial scald, soft scald, core flush, and greasiness is reduced by 1-MCP. J. Agric. Food Chem. 47:3063–3068.

Fan, X. and J.P. Mattheis. 1999a. Impact of 1-methylcyclopropene and methyl jasmonate on apple volatile production. J. Agric. Food Chem. 47:2847–2853.

Fan, X. and J.P. Mattheis. 1999b. Methyl jasmonate promotes apple fruit degreening independently of ethylene action. HortScience 34:310–312.

Fan, X. and J.P. Mattheis. 2000. Yellowing of broccoli in storage is reduced by 1-methylcyclopropene. HortScience 35:885–887.

Fan, X. and J.P. Mattheis. 2001. 1-Methylcyclopropene and storage temperature influence responses of 'Gala' apple fruit to gamma irradiation. Postharvest Biol. Technol. 23:143–151.

Faragher, J.D., E. Wachtel, and S. Mayak. 1986. Changes in the physical state of membrane lipids during senescence of rose petals. Plant Physiol. 83:1037-1042.

Feng, X., A. Apelbaum, E.C. Sisler, and R. Goren. 2000. Control of ethylene responses in avocado fruit with 1-methylcyclopropene. Postharvest Biol. Technol. 20:143-150.

Flores, F., F. El Yahyaoui, G. de Billerbeck, F. Romojaro, A. Latche, M. Bouzayen, J.C. Pech, and Ambid. 2002. Role of ethylene in the biosynthetic pathway of aliphatic ester aroma volatiles in Charentais cantaloupe melons. J. Exp. Bot. 53:201–206.

Gaines, J.C. 1957. Cotton insects and their control in the United States. Ann. Rev. Entomol. 2:319-338.

Gan, S., and R.M. Amasino. 1997. Making sense of senescence: Molecular genetic regulation and manipulation of leaf senescence. Plant Physiol. 113:313-319.

Gepstein, S. and K.V. Thimann. 1981. The role of ethylene in the senescence of oat leaves. Plant Physiol. 68:349-354.

Golding, J.B., D. Shearer, S.G. Wyllie, and W.B. McGlasson. 1998. Application of 1-MCP and propylene to identify ethylene-dependent ripening processes in mature banana fruit. Postharvest Biol. Technol. 14:87–98.

Goodman, A. 1955. Correlation between cloud shade and shedding in cotton. Nature. 176:39.

Guinn G. 1975. Water deficit and ethylene evolution by young cotton bolls. Plant Physiol. 57:403-405.

Guinn, G. 1976. Nutritional stress and ethylene evolution by young cotton bolls. Crop Sci. 16:89–91.

Guinn, G. 1981. Fruit age and changes in abscisic acid content, ethylene production, and abscission rate of cotton fruits. Plant Physiol. 69:349-352.

Guinn, G. 1982. Causes of square and boll shedding in cotton. USDA Tech. Bull. 1672:1–22. U.S. Gov. Print. Office, Washington, DC.

Hake, K., T. Kerby, and W. McCarty. 1989a. Effect of cold weather on yield and quality. *In* Cotton Physiology Today Newletter. National Cotton Council, Memphis, TN, Technical Serivices. Oct. 1989.

Hake K., G. Guinn, and D. Oosterhuis. 1989b. Environmental causes of shed. *In* Cotton Physiology Today Newletter. National Cotton Council, Memphis, TN, Technical Services. Dec. 1989.

Hake, K. and B. Meredith. 1990. Full season yields from short season weather. *In* Cotton Physiology Today Newletter. vol. 1, no. 9. National Cotton Council, Memphis, TN, Technical Services.

Hake, K., J.C. Banks, F. Bourland, P. Sasser, P. Tugwell, and R. Willford. 1992a. Boll weathering. *In* Cotton Physiology Today Newsletter vol. 3, no. 10. National Cotton Council, Memphis, TN, Technical Services.

Hake, K., F. Carter, J. Mauney, N. Namken, J. Heitholt, T. Kerby and B. Pettigrew. 1992b. Square retention. *In* Cotton Physiology Today Newletter vol. 3, no. 6. National Cotton Council, Memphis, TN, Technical Services.

Hanson, A.D. and H. Kende. 1976. Biosynthesis of wound ethylene in morning-glory flower tissue. Plant Physiol. 57:538-541.

Hirayama T., J.J. Kieber, N. Hirayama, M. Kogan, and P. Guzm´an. 1999. Responsive - to-antagonists1, a Menkes/Wilson disease-related copper transporter, is required for ethylene signaling in *Arabidopsis*. Cell 97:383–93.

Hofman, P.J., M. Jobin-Décor, G.F. Meiburg, A.J. Macnish, and D.C. Joyce. 2001. Ripening and quality responses of avocado, custard apple, mango and papaya fruit to 1-methylcyclopropene. Aust. J. Exp. Agric. 41:567–572.

Holman, E.M. and D.M. Oosterhuis. 1999. Cotton photosynthesis and carbon partitioning in response to floral bud loss due to insect damage. Crop Sci. 39:1347-1351.

Horton, R. F. and D. J. Osborne. 1967. Senescence, abscission and cellulose activity in *Phaseolus vulgaris*. Nature 214:1086-1088.

Iieyes, J.A. and J.W. Johnston. 1998. 1 -methylcyclopropene extends *Cymbidium* orchid vaselife and prevents damaged pollinia from accelerating senescence. New Zealand Journal of Crop and Horticultural Science 26:319-324.

Jackson, M.B. and D.J. Osborne. 1970. Ethylene, the natural regulator of leaf abscission. Nature 225:1019-1022.

Jenkins, J.N., J.C. McCarty, and W.L. Parrot. 1990. Effectiveness of fruiting sites in cotton: Yield. Crop Sci. 30:365-369.

Jenkins, J.N. and J.C. McCarty. 1995. Useful tools in managing cotton production: End of season plant maps. Mississippi Agriculture and Forestry Experiment Station, Bulletin No. 1024. Starkville, MS.

Jeong, J., D.J. Huber, and S.A. Sargent. 2002. Influence of 1-methylcyclopropene (1-MCP) on ripening and cell-wall matrix polysaccharides of avocado (*Persea americana*) fruit. Postharvest Biol. Technol. 25:241–364.

Jiang, Y., J.D. Joyce, and L.A. Terry. 2001. 1-methylcyclopropene treatment affects strawberry fruit decay. Postharvest Biol. Technol. 23:227–232.

Jiang. Y., and J.D. Joyce. 2002. 1-methylcyclopropene treatment effects on intact and fresh cut apple. J. Hort. Sci. Biotech. 77:19-21.

Jiang, Y., Q. Sheng, X. Zhou, M. Zhang, and X. Liu. 2002a. Regulation of coriander senescence by 1-methylcyclopropene and ethylene. Postharvest Biol. Technol. 26:339–345.

Jiang, Y., J.D. Joyce, A.J. Macnish, and Y.M. Jiang. 2002b. Softening response of banana fruit treated with 1-methylcyclopropene to high temperature exposure. J. Plant Growth Regul. 36:7–11.

Johnson, P.R. and J.R. Ecker. 1998. The ethylene gas signal transduction pathway: A molecular perspective. Annu. Rev. Genet. 32:227-254.

Jordan, W.R., P.W. Morgan, and T.L. Davenport. 1972. Water stress enhances ethylene-mediated leaf abscission. Plant Physiol. 50:756-758.

Kao, C.H. and S.F. Yang. 1983. Role of ethylene in the senescence of detached rice leaves. Plant Physiol. 83:881-885.

Kawase, M. 1978. Anaerobic elevation of ethylene concentration in waterlogged plants. Amer. J. Bot. 65(7):736-740.

Kende H. 1993. Ethylene biosynthesis. Plant Physiol. 44:283–307.

Kieber J.J., M. Rothenberg, G. Roman, K.A. Feldmann, J.R. Ecker. 1993. *CTR1*, a negative regulator of the ethylene response pathway in *Arabidopsis*, encodes a member of the Raf family of protein kinases. Cell. 72:427–41

Kieber JJ. 1997. The ethylene response pathway in *Arabidopsis.* Annu. Rev. Plant Physiol. Plant Mol. Biol. 48:277–96

Kruzmane, D., L. Jankevicab, and G. Ievinsh. 2002. Effect of regurgitant from *Leptinotarsa decemlineata* on wound responses in *Solanum tuberosum* and *Phaseolus vulgaris*. Physiologia Plantarium. 115:577–584.

Ku, V.V.V., R.B.H. Wills, and S. Ben-Yehoshua. 1999. 1-Methylcyclopropene can differentially affect the postharvest life of strawberries exposed to ethylene. HortScience 34:119–120.

Lange, M. and K. Hake. 1992. Late planted cotton. *In* Cotton Physiology Today Newletter vol. 2, no. 7. National Cotton Council, Memphis, TN, Technical Services.

Lege, K.E., J.T. Cothren and P.W. Morgan. 1997. Nitrogen fertility and leaf age effects on ethylene production of cotton in a controlled environment. Plant Growth Regulation 22**:**23–28.

Lieberman, M. 1979. Biosynthesis and action of ethylene. Plant Physiol. 30:533-591.

Lipe, J.A. and P.W. Morgan. 1972. Ethylene a regulator of young fruit abscission. Plant Physiol. 51:949-953.

Malik, M.N.A., D.G. Edwards, and J.P. Evenson. 1981. Effects of flower bud removal and nitrogen supply on growth and development of cotton *(Gossypium hirsutum* L.). Aust. J. Plant Physiol. 8: 285-91.

Martin, JR., W.R., P.W. Morgan, W.L. Sterling, and C.M. Kernerley. 1988. Cotton fleahopper and associated microorganisms as components in the production of stress ethylene by cotton. Plant Physiol. 87:280-285.

Mattoo, A.K. and J.C. Suttle. 1991. The plant hormone ethylene. CRC Press, Boca Raton, FL.

McMichael, B.L., W.R. Jordan, and R.D. Powell. 1972. An effect of water stress on ethylene production by intact cotton petioles. Plant Physiol. 49:658-660

McMichael, B.L. and W.R. Jordan. 1973. Abscission processes in cotton: Induction by plant water deficit. Agron. J. 65:202-204.

McMichael, B.L. 1979. The influence of water stress on flowering and fruiting in cotton. Proc. Beltwide Cotton Prod. Res. Phoenix, AZ. Conf. National Cotton Council of America. p. 301-302.

Michaeli, R., S. Philosoph-Hadas, J. Riov, and S. Meir. 1999. Chilling-induced leaf abscission of *Ixora coccinea* plants. I. Induction by oxidative stress via increased sensitivity to ethylene. Plant Physiol. 107:166–173.

Mir, N.A., E. Curell, N. Khan, M. Whitaker, and R.M. Beaudry. 2001. Harvest maturity, storage temperature, and 1-MCP application frequency alter firmness, retention and chlorophyll fluorescence of 'Redchief Delicious' apples. J. Am. Soc. Hort. Sci. 126:618–624.

Moore, D. J. 1968. Cell wall dissolution and enzyme secretion during leaf abscission. Plant Physiol. 43: 1545-1559.

Morgan, P.W. and W.C. Hall. 1964. Accelerated release of ethylene by cotton following application of indoly-3-acetic acid. Nature 99: 4914.

Morgan, P.W. 1969. Stimulation of ethylene evolution and abscission in cotton by 2-chloroethanephosphonic acid. Plant Physiol. 44:337-341.

Morgan P.W., C.J. He, and M.C. Drew. 1992 Intact leaves exhibit a climacteric-like rise in ethylene production before abscission. Plant Physiol. 1992 100(3):1587–1590.

Pettigrew, W.T., J.J. Heitholt, and W.R. Meredith. 1992. Early season floral bud removal and cotton growth, yield, and fiber quality. Agron. J. 84:209-214.

Porat, R., B. Weiss, L. Cohen, A. Daus, R. Goren, and S. Droby. 1999. Effects of ethylene and 1-methylcyclopropene on the postharvest qualities of 'Shamouti' oranges. Postharvest Biol. Technol. 15:155-163.

Reddy, K.R., G.H. Davidonis, A. S. Johnson, and B.T. Vinyard. 1999. Temperature regime and carbon dioxide enrichment alter cotton boll development and fiber properties. Agron. J. 91:851–858.

Rethwisch M.D., J. Milke, M. Luna, D.M. Ramos, J. Wellman, A. Dulmage, M. Williams, R. Montanez, and J. Cardenos. 2006. Evaluation of Re®Tain on four low desert cotton varieties during 2005 heat stress conditions. 2006 season summary. Cotton report. 2006. The University of Arizona Cooperative Extension Tucson, AZ. p. 165-172

Rikin, A., E. Chalutz, and J.D. Anderson. 1984. Rhythmicity in ethylene production in cotton seedlings. Plant Physiol. 75:493-495.

Rodriguez, F.I., J.J. Esch, A.E. Hall, B.M. Binder, G.E. Schaller, and A.B. Bleecker. 1999. A copper cofactor for the ethylene receptor ETR1 from Arabidopsis. Science 283:996–98.

Roman G, B. Lubarsky, J.J. Kieber, M. Rothenberg, J.J. Ecker. 1995. Genetic analysis of ethylene signal transduction in *Arabidopsis thaliana*: Five novel mutant loci integrated into a stress response pathway. Genetics 139:1393–409

Rupasinghe, H.P.V., D.P. Murr, G. Palyath, and J.R. DeEll. 2000. Suppression of α-farnesene synthesis in 'Delicious' apples by aminoethoxyvinylglycine (AVG) and 1-methylcyclopropene (1-MCP). Physiol. Mol. Biol. Plants. 6:195–198.

Sadras, V.O. and L.J. Wilson. 1998. Recovery of cotton crops after early season damage by thrips (Thysanoptera)**.** Crop Sci. 38:399–409.

SAS Institute. 1999. The SAS System for Windows – Release 9.1.3. SAS Institute, Cary, NC.

Selvarajah, S., A.D. Bauchot, and P. John. 2001. Internal browning in cold-stored pineapples is suppressed by a postharvest application of 1-methylcyclopropene. Postharvest Biol. Technol. 23:167–170.

Serek, M., G. Tamari, E.C. Sisler, and A. Borochov. 1995a. Inhibition of ethylene-induced cellular senescence symptoms by 1-methylcyclopropene, a new inhibitor of ethylene action. Physiol. Plantarum. 94(2):227-229.

Serek, M., E.C. Sisler, and M.S. Reid. 1995b. 1-Methylcyclopropene, a novel gaseous inhibitor of ethylene action, improves the life of fruits, cut flowers and potted plants. Acta Hort. 394:337–345.

Sisler, E.C., E. Dupille, and M. Serek. 1996. Effect of 1-methylcyclopropene and methylenecyclopropene on ethylene binding and ethylene action on cut carnations. Plant Growth Regul. 18:79–86.

Sisler, E.C. and M. Serek. 1997. Inhibitors of ethylene responses in plants at the receptor level: Recent developments. Physiol. Plantarum. 100:577-582.

Sisler, E.C. and M. Serek. 1999. Compounds controlling the ethylene receptor. Bot. Bull. Acad. Sin. 40:1-7.

Suttle, J. C. and H. Kende. 1980. Ethylene action and loss of membrane integrity during petal senescence in *Tradescantia*. Plant Physiol. 65:1067-1072.

Suttle, J.C. and J.F. Hultstrand. 1991. Ethylene-induced leaf abscission in cotton seedlings: The physiological bases for age-dependent differences in sensitivity. Plant Physiol. 95:29-33.

Taiz, L. and E. Zeiger. Ethylene: The gaseous hormone. 2006. *In* Plant Physiology. 4th ed. Sinauer Associates, Inc., Publishers, Sunderland, Massachusetts. p. 519-535.

Tian, M.S., S. Prakash, H.J. Elgar, H.Young, D.M. Burmeister, and G.S. Ross. 2000. Responses of strawberry fruit to 1-methylcyclopropene (1-MCP) and ethylene. Plant Growth Regul. 32:83–90.

Tsuchiya, T., H. Ohta, K. Okawa, A. Iwamatsu, H. Shimada, T. Masuda, and K. Takamiya. 1999. Cloning of chlorophyllase, the key enzyme in chlorophyll degradation: Finding of a lipase motif and the induction by methyl jasmonate. Proc. of the National Academy of Science of the United States of America. 96 (26): 15362-15367.

USDA. 1993. The classification of cotton. USDA-AMS, Agric. Handb. 594. U.S. Gov. Print. Office, Washington, DC.

Walling, L.L. 2000. The myriad plant responses to herbivores. J. Plant Growth Regul. 19:195–216.

Wang K.L.C., H. Li, and J.R. Ecker. 2002. Ethylene biosynthesis and signaling networks. Plant Cell. 14:131-151.

Watkins, C.B., J.F. Nock, and B.D. Whitaker. 2000. Responses of early, mid and late season apple cultivars to postharvest application of 1-methylcyclopropene (1-MCP) under air and controlled atmosphere storage conditions. Postharvest Biol. Technol. 19:17–32.

Wells, R. and W.R. Meredith, Jr. 1983. Comparative growth of obsolete and modern cotton cultivars. II. Reproductive dry matter partitioning. Crop Sci. 24:863-867.

Wilk, J.D., D. Holland, E.E. Goldschmidt, J. Riov, and Y. Eyal. 1999. Chlorophyll breakdown by chlorophyllase: Isolation and functional expression of the Chlase 1 gene from ethylene-treated citrus fruit and its regulation during development. Plant J. 20(6):653-661.

Willis, R.B., V.V. Ku, and M.A. Warton. 2002.Use of 1-methylcyclopropene to extend the postharvest life of lettuce. J. Sci. Food Agric. 82:1253–1255.

Wilson, L.J., V.O. Sadras, S.C. Heimoana, and D. Gibb. 2003. How to succeed by doing nothing: Cotton compensation after simulated early season pest damage. Crop Sci. 43:2125–2134.

Worley S., T. W. Culp, and D. C. Harrell. 1974. The relative contributions of yield components to lint yield of upland cotton, *Gossypium hirsutum* L. Euphytica. 23(2): 399-403.

Yang, G., D. Rhodes, and R.J. Jolly. 1996. Effects of high temperature on membrane stability and chlorophyll fluorescence in glycine-deficient and glycinebetaine-containing maize lines. Aust. J. Plant Physiol. 23:437-443.

Yang S.F. and N.E. Hoffman. 1984. Ethylene biosynthesis and its regulation in higher plants. Plant Physiol. 35:155-89.

Yu, Y. and S.F. Yang. 1980. Biosynthesis of wound ethylene. Plant Physiol. 66:281-285.

Zhao D., K.R. Reddy, V.G. Kakani, S. Koti, and W. Gao. 2005. Physiological causes of cotton fruit abscission under conditions of high temperature and enhanced ultraviolet-B radiation. Physiol. Plantarum 124:189–199.

APPENDIX A

CROP PRODUCTION PRODUCTS USED IN 2005 COTTON STUDY

The following products were used at the rates indicated for the designated weeds or pest.

Preplant	
Broadleaf weeds and annual grasses	Treflan® 4EC – trifluralin: 1.86 L ha^{-1} α,α,α,-trifluoro-2,6-dinitro-*N,N* dipropyl-*p*-tolidine
Early Season	
Thrips (*Thrips tabaci*)	Temik® 15G – aldicarb: 5.61 kg ha^{-1} [2-methyl-2-(methylthio)propionaldehyde 0-(methylcarbomoy)]
	Bidrin® 8 – dicrotophos: 0.29 L ha^{-1} Dimethyl phosphate of 3-hydroxy-*N,N*-Dimethyl-*cis*-crotonamide
Annual grasses	Dual® II – metolachlor: 1.17 L ha^{-1} 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-Methoxy-1-methylethyl)acetamide
	Caporal® 4L – prometryn: 2.34 L ha^{-1} 2,4-bis(isopropylamino)-6-methylthio)-*S*-triazine
Broadleaf weeds	Roundup WeatherMax® – glyphosate: 1.61 L ha^{-1} N-(phosphonomethyl)glycine
Plant Growth Regulator	Pentia® – mepiquat pentaborate: 0.58 L ha^{-1} N,N-dimethylpiperidiniurn pentaborate

Harvest Aides	Ginstar® Thidiazuron: 0.58 L ha^{-1} 5-Phenylcarbamoylamino-1,2,3-thiadiazole; diruron: 3-(3,4 Dichlorophenyl)-1,1-dimethylurea; *N*'-(3,4-dichlorophenyl)-*N*,*N*-dimethylurea Finish 6 Pro® - ethephon: 1.17 L ha^{-1} (2-chloroethyl) phosphonic acid; cyclanilide: 1-(2,4-dichlorophenylaminocarbonyl)-cyclopropane carboxylic acid Paraquat dichloride: 0.29 L ha^{-1} 1,1'-dimethyl-4,4'- bipyridyliumdichloride

APPENDIX B

CROP PRODUCTION PRODUCTS USED IN 2005 COTTON STUDY

The following products were used at the rates indicated for the designated weeds or pest.

Preplant	
Broadleaf weeds and annual grasses	Treflan® 4EC – trifluralin: 1.86 L ha^{-1} α,α,α,-trifluoro-2,6-dinitro-*N,N* dipropyl-*p*-tolidine
Early Season	
Thrips (*Thrips tabaci*)	Temik® 15G – aldicarb: 5.61 kg ha^{-1} [2-methyl-2-(methylthio)propionaldehyde 0-(methylcarbomoy)]
	Bidrin® 8 – dicrotophos: 0.29 L ha^{-1} Dimethyl phosphate of 3-hydroxy-*N,N*-Dimethyl-*cis*-crotonamide
Annual grasses	Dual® II – metolachlor: 1.17 L ha^{-1} 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-Methoxy-1-methylethyl)acetamide
	Caporal® 4L – prometryn: 2.34 L ha^{-1} 2,4-bis(isopropylamino)-6-methylthio)-*S*-triazine
Broadleaf weeds	Roundup WeatherMax® – glyphosate: 1.61 L ha^{-1} N-(phosphonomethyl)glycine
Plant Growth Regulator	Pentia® – mepiquat pentaborate: 0.58 L ha^{-1} N,N-dimethylpiperidiniurn pentaborate

Harvest Aides	Ginstar® Thidiazuron: 0.58 L ha^{-1} 5-Phenylcarbamoylamino-1,2,3-thiadiazole; diruron: 3-(3,4 Dichlorophenyl)-1,1-dimethylurea; *N*'-(3,4-dichlorophenyl)-*N*,*N*-dimethylurea Finish 6 Pro® - ethephon: 1.17 L ha^{-1} (2-chloroethyl) phosphonic acid; cyclanilide: 1-(2,4-dichlorophenylaminocarbonyl)-cyclopropane carboxylic acid

VITA

Justin Jack Scheiner, son of John and Pam Scheiner, was born in La Marque, Texas on June 27, 1981. He graduated from Normangee High School in May of 1999. Justin received a Bachelor of Science degree in horticulture and crop science from Sam Houston State University in May 2005. He was employed at Color Spot Nurseries from 2002 to 2005 as a grower and pesticide applicator. Upon completion of his B.S. he entered the Master of Science program at Texas A&M University. He received his M.S. degree in May 2007. Justin plans to pursue a Ph.D. in horticulture at Cornell University. His permanent address is 1600 Welsh Avenue, College Station, TX 77840.