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Ethylene Inhibitors Increase Net Assimilation Rate and Cotton Boll Dry Matter Under Drought

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Abstract

Although the ethylene inhibitors role on reduction rate of boll abscission in cotton plants submitted to drought is being recently reported, its effects on photosynthesis performance and on cotton boll dry matter across the sympodial branch is scarce. Thus, the objective of this study was to evaluate the cotton photosynthesis and its boll dry matter performance across the reproductive branches via positional mapping in plants sprayed with ethylene inhibitors and submitted to water deficit. 1-methylcyclopropene (1-MCP), an inhibitor of ethylene action and aminoethoxyvinylglycine (AVG), an inhibitor of its synthesis, were sprayed on cotton plants alone and in association. Treatments were composed by (T_1) control, where deionized water was sprayed; (T_2) sprayed with AVG at 0.15 g a.i. L^{-1}; (T_3) 1-MCP at 0.076 g a.i. L^{-1}; (T_4) AVG at 0.15 g a.i. L^{-1} plus 1-MCP at 0.076 g a.i. L^{-1}; (T_5) AVG at 0.15 g a.i. L^{-1} twice at each seven days; (T_6) 1-MCP sprayed at 0.076 g a.i. L^{-1} twice using the same interval and (T_7) AVG at 0.15 g a.i. L^{-1} plus 1-MCP at 0.076 g a.i. L^{-1} twice at each seven days. The ethylene inhibitors sustained higher photosynthesis performance and higher boll dry mass across reproductive branches independent of compound, its combination or entries number. Highlight that a AVG (T_2) or its 1-MCP association in two entries (T_7) showed the best performance for dry matter accumulation, especially in the two first reproductive branches, while they maintained the highest photosynthesis rates at the end of stress period.

Keywords: drought, ethylene inhibitors, abiotic stress, plant growth regulator

1. Introduction

Abiotic and biotic stresses represent the major constraints that result in agricultural losses on the global scale, and projected climate changes could increase their negative effects in the future (IPCC, 2007; Fischer & Schar, 2010).

Cotton (*Gossypium hirsutum* L. r. *latifolium*) is the major fiber crop; however, cotton yields are often limited due to the extreme sensitivity of this crop to environmental stressors, such as temperature variation and drought events, so that cotton plants are continuously exposed to various biotic and abiotic stresses during growth in their natural environment. Under such conditions, cotton plants can evoke intricate mechanisms to perceive external signals, allowing the optimal response to the environmental conditions. As components of these mechanisms, plant hormones, including abscisic acid (ABA), jasmonic acid (JA), salicylic acid (SA) and ethylene (ET), are endogenous, low molecular weight molecules that primarily regulate the protective responses of plants against both biotic and abiotic stresses via synergistic and antagonistic actions, which are referred to as signaling crosstalk (Fujita et al., 2006). Among these molecules, ethylene is considered to be a stress hormone, and increased ethylene levels have been verified when plants are subjected to abiotic and biotic stresses (Taiz & Zeiger, 2010). Thus, under field conditions, cotton plants are often exposed to environmental stresses, such as extreme temperatures, solar radiation and water availability, particularly during the critical phases as such at initial reproductive and boll development stages. During these periods, stress alters the hormone balance and triggers the activation of pathways involved in the stress response, resulting in the abscission of squares and young bolls and the abortion of flowers, causing a reduced seed cotton yield and, consequently, lower fiber yield (Brito et al., 2011; Stewart et al., 2010). As above described, a common response of cotton plants when submitted to stress is its increased ethylene biosynthesis; and although this comportment is very well established and its role in the regulation of the abscission process in cotton fruit is extensively reported, the relationship of

ethylene with boll dry mass across of the reproductive branches via positional plant mapping and its photosynthetic responses to water deficit has not been documented.

In this context, we hypothesized that spraying cotton plants with 1-MCP, a compound that inhibits the action of ethylene by occupying the receptor site, and/or AVG, which inhibits its synthesis binding to aminociclopropane-1-carboxylic (ACC) synthase enzyme and blocking the conversion of S-adenosylmethionine to 1-aminoclopropane-1-carboxilic acid (ACC), the immediate precursor in the ethylene biosynthesis pathway, could thus mitigate plant stressors, which are common during all growth seasons, particularly in the reproductive phase. Thus, to gain more comprehensive knowledge in this respect, the objective of this research was to evaluate the performance of cotton boll dry mass across the reproductive branches via positional mapping and characterize its photosynthesis responses when sprayed with ethylene inhibitors and submitted to water deficit regime.

2. Materials and Methods

2.1 Plant materials and Growth Conditions

To investigate whether these compounds (1-MCP and AVG) could mitigate the negative effects of ethylene on cotton photosynthesis performance and boll dry mass, analyzes were carried out under greenhouse conditions at Embrapa experimental station, located in the city of Santo Antonio de Goiás, Goiás, Brazil. Air temperature and relative humidity were maintained at 28 ± 2 ^{o}C and 60 ± 10%, respectively, via a climatic control system installed within of this greenhouse. At time of gas exchange analyzes, the photosynthetically active radiation (PAR) was measured using a Quantum Sensor LI-COR (Q-45556) attached to the LI-COR 6400 (LICOR-6400, LI-COR Inc., Lincoln, NE, USA). Photosynthetic photon flux density (PPFD) varied from 900 to 1641 μmol m^{-2} s^{-1} during stress cycle. The experiment was conducted in a completely randomized design with four replications, where were done the plant mapping aiming to know its bolls distribution, boll numbers and its boll dry mass across the reproductive branches (sympodial branches); additionally, its photosynthesis responses and photosynthetic pigments were also analyzed after water stress imposing and ethylene inhibitors applications; water deficit regime was imposed at first flower emergence.

2.2 Procedures and Growth Regulators Treatments

For this study was used a substrate compounded by washed sand and peat - 1:1, v/v); for field capacity procedures, each PVC column (30 cm diameter and 1.0 m of height) was filled with 48.0 kg of the mixture as described above; before filling, small holes were cut into the bottom of the plate, used as support for column aiming facilitate initial drainage. Subsequently, water was added to each column until saturation. After, all columns were covered with plastic and put aside to drain for 24 hours, after which the holes were then sealed and all columns were weighed to obtain the field capacity. The experimental unit consisted of one cotton plant sowed per column. The BRS 293 cotton cultivar was chosen for this study because its higher sensitivity to water deficit (unpublished data); after germination, the plants were irrigated regularly, maintaining 80% of field capacity until 41 days after emergence (DAE), before the first flower emergence.

At the emergence of the first flower (at 42 DAE), plants were subjected to water deficiency via withdrawal of irrigation procedures. Twenty-four hours after last irrigation, the 1-MCP and AVG treatments were sprayed separately and its association with a CO_2 backpack sprayer calibrated to deliver 200 L ha^{-1}. Treatments consisted of application of (T_1) control, where only deionized water was sprayed; (T_2) sprayed with AVG at 0.15 g a.i. / l; (T_3) 1-MCP at 0.076 g a.i. / l; (T_4) AVG at 0.15 g a.i. / l plus 1-MCP at 0.076 g a.i. / l; (T_5) AVG at 0.15 g a.i. / l twice at each seven days; (T_6) 1-MCP sprayed at 0.076 g a.i. / l twice using the same interval and (T_7) AVG at 0.15 g a.i. / l plus 1-MCP at 0.076 g a.i. / l twice at each seven days. For all treatments were used the adjuvant Silwet L-77 added to the spraying solution at a rate of 0.035% v/v. The doses and entry intervals were defined based in its numbers of bolls retained in preliminary trials. After ethylene inhibitors applications, the leaf water potential at predawn (LWP_{pred}) (between 4:30 and 5:00 a.m.) was monitored at each two days aiming to define the key point of water status adequate to make the gas exchange analyses and sampling for photosynthetic pigments determinations (Ackerson et al., 1977; Parsons et al., 1979; Marani et al., 1985).

2.3 Physiological Measurements

The net assimilation rate (*P*n), stomatal conductance (*g*s) and transpiration rate (*E*) were measured between 9:00 and 11:00 h under artificial photosynthetic photon flux (PPF) (1,100 μmol m^{-2} s^{-1}) using a portable photosynthesis system infrared gas analyzer (LI-COR 6400XT, LI-COR Biosciences) (Ullah et al., 2008). For measurements, a CO_2 cartridge was used and a 6400-01 CO_2 Injector System controlled the CO_2 partial pressure entering the cuvette (C_a, μbar). For all ethylene inhibitors and control treatments, measurements were started on

one youngest expanded leaf on four different plants (n = 4). The leaves used for gas exchange measurements were tagged to allow making these analyses using always the same leaves. The mid to distal portion of each leaf blade was inserted in the leaf chamber for gas-exchange measurements. For photosynthetic pigments determinations, chlorophyll was extracted from leaf disks using procedures described by Hiscox and Israelstam (Hiscox & Israelstam, 1979). Each disc was cut into smaller pieces and placed in a test tube containing 5 mL of dimethyl sulfoxide (DMSO). All test tubes were incubated at 70 ºC for 30 min, until all visible green pigmentation was removed, attained the extraction of chlorophyll. After cooling the chlorophyll extract, 3 mL aliquot was transferred to a cuvette for determination of chlorophyll a, chlorophyll b and carotenoids absorbency using a spectrophotometer at 665, 649 and 480 nm. Absorption measurements were used to quantify chlorophyll concentrations based on equations reported by Wellburn (1994).

2.4 Plant Mapping

For plant mapping procedures, reproductive structure (squares and flowers) were tagged at its emergence and registered its abscission event in each position across of the sympodial branches. At the end of stress period, bolls were removed and separated by each fruiting site on each sympodial branch. The bolls harvested on each fruiting branch by positions one through seven were recorded with the cotyledonary node counted as zero. Cotton bolls number across each sympodial branch was recorded and its boll dry mass was measured via oven-dried at 70 ^{o}C with forced-air circulation until constant weight.

2.5 Statistical Procedures

The homogeneity of variances was tested by the Bartlett test, and the data were subsequently subjected to analysis of variance (ANOVA). The Least Significant Difference (LSD) among the means was statistically analyzed using Student's t-test ($p < 0.05$) for physiological parameters, cotton boll number and total boll dry mass. Additionally, the most interesting contrasts were estimate via orthogonal contrasts.

3. Results

The LWP_{pred} of those leaves maintained under well-watered conditions (until 41 days after emergence) were always kept at -0.3 MPa or greater (less negative) at predawn (data not shown). At first day after withdrawal irrigation the mean of LWP_{pred} for all treatments were kept close at -0.55 MPa at predawn, reaching nearly -1.10 MPa and -1.80 MPa at ninth and sixteenth day after stress imposing, respectively.

Gas exchange analysis of untreated control with ethylene inhibitors and submitted to stress showed a photosynthesis decline of 24.6% at the end of stress period (at -1.80 MPa of LWP_{pred}) compared to those sprayed with these compounds independent of combinations and its entries number. Additionally, when the untreated control was compared to T_2 (sprayed with AVG at 0.15 g a.i. L^{-1}) and with T_7 (AVG at 0.15 g a.i. L-1 plus 1-MCP at 0.076 g a.i. L-1 twice at each seven days) there were a photosynthesis reduction of 43.70% and 26.30%, respectively (Figure 1A).

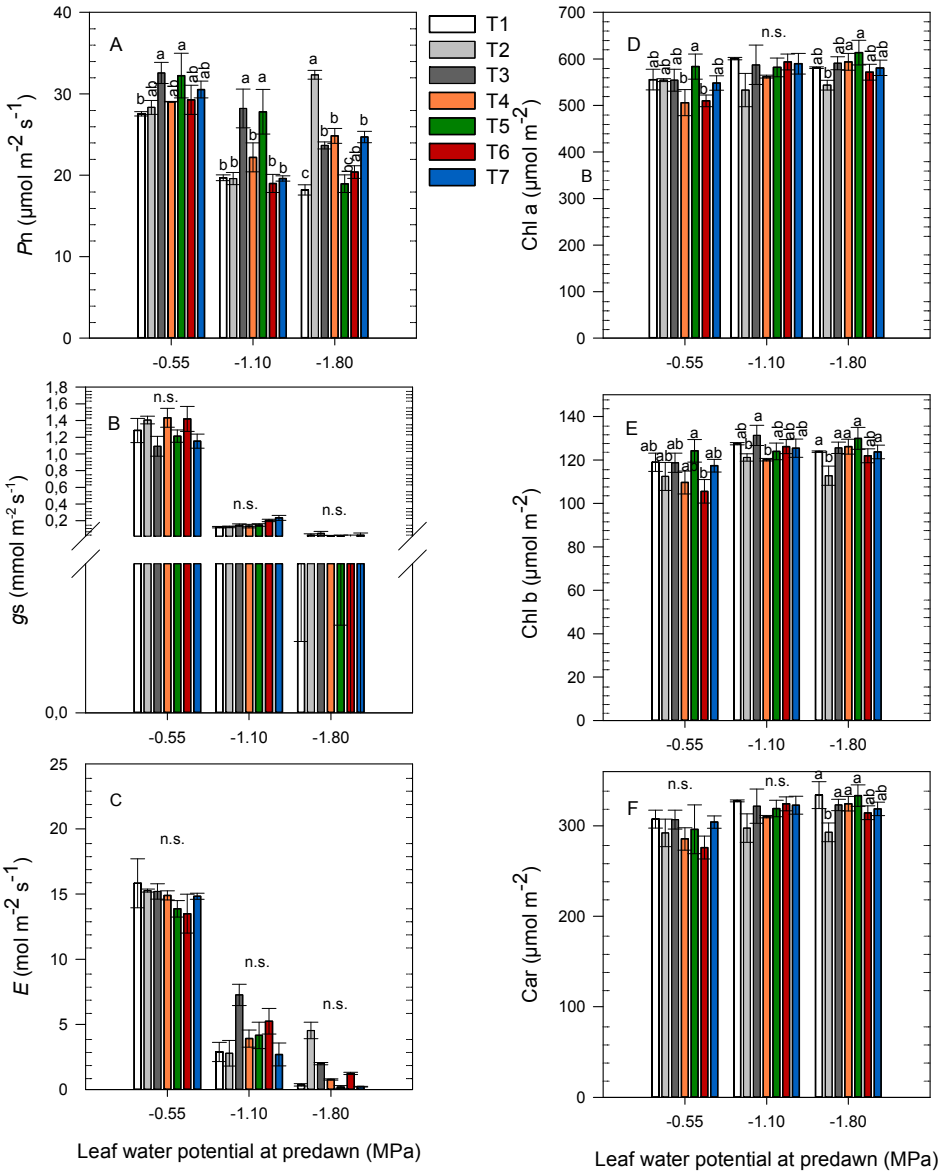

Figure 1. Gas exchange performance and photosynthetic pigments from cotton plants sprayed with ethylene inhibitors

Treatments consisted of application of (T_1) control, where only deionized water was sprayed; (T_2) sprayed with AVG at 0.15 g a.i. L^{-1}; (T_3) 1-MCP at 0.076 g a.i. L^{-1}; (T_4) AVG at 0.15 g a.i. L^{-1} plus 1-MCP at 0.076 g a.i. L^{-1}; (T_5) AVG at 0.15 g a.i. L^{-1} twice at each seven days; (T_6) 1-MCP sprayed at 0.076 g a.i. L^{-1} twice using the same interval and (T_7) AVG at 0.15 g a.i. L^{-1} plus 1-MCP at 0.076 g a.i. L^{-1} twice at each seven days. Means followed by the same letter are not significantly different at the $p < 0.05$ level by Student's statistical tests (LSD). Error bars represent the standard errors of four plants, each representing a replication. *P*n, *g*s, *E*, Car, Chor a and chlor b means net assimilation rate, stomatal conductance, transpiration rate, carotenoids content, chlorophyll *a* content and chlorophyll *b* content, respectively.

In this sense, our data support that an entry of compounds 1-MCP (T_2) or its AVG combination (T_7) were able to sustain the highest photosynthesis rate at the end of stress period, while there were not significant differences for stomatal conductance and transpiration rate (Figures 1B and 1C). Although, were verified significant differences for chlorophylls and carotenoids across measurements in the evaluated water status levels (Figures 1D, 1E and 1F); their magnitudes were less evident. This tendency was observed for photosynthesis, stomatal conductance and transpiration rate across ethylene inhibitor treatments and stress level (Figures 1A, 1B and 1C), where reductions were linear for these parameters across the stress level, showing that photosynthesis was limited by

declining *g*s.

Relative to ethylene inhibitor effects on boll number and its total boll dry mass there were distinct effects; where were verified significant differences just for boll dry mass (Figure 2B). In general, again the better performance was verified in the plants sprayed with AVG at 0.15 g a.i. L^{-1} (T_2) and AVG at 0.15 g a.i. L^{-1} plus 1-MCP at 0.076 g a.i. L^{-1} twice at each seven days (T_7).

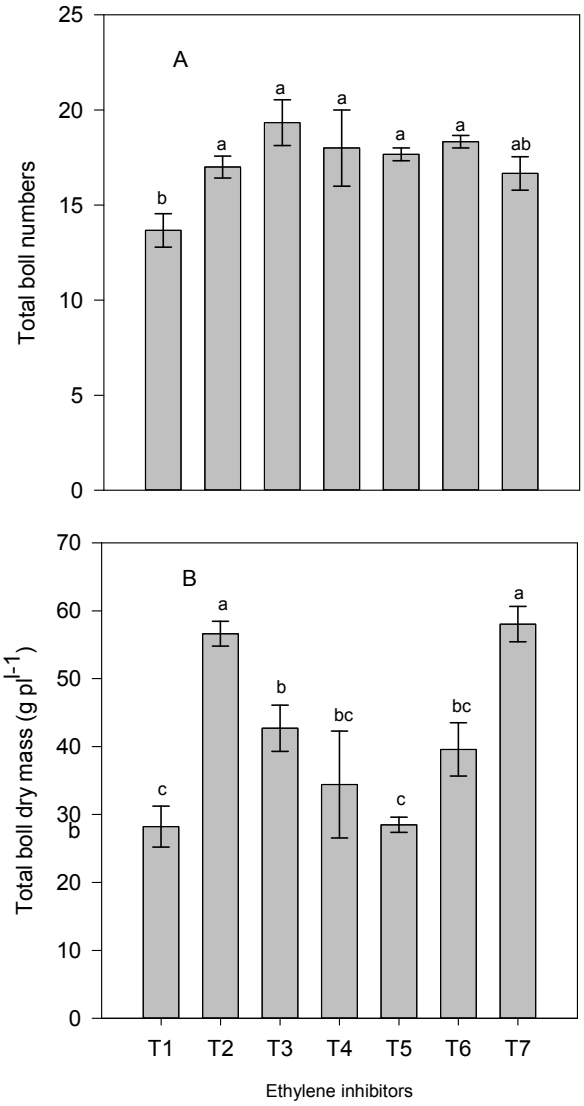

Figure 2. Boll quantity and its total dry mass performance obtained by plant positional mapping

Total boll number (A) and total boll dry mass (B) as a result of cotton plant sprayed with ethylene inhibitors. Treatments consisted of application of (T_1) control, where only deionized water was sprayed; (T_2) sprayed with AVG at 0.15 g a.i. L^{-1}; (T_3) 1-MCP at 0.076 g a.i. L^{-1}; (T_4) AVG at 0.15 g a.i. L^{-1} plus 1-MCP at 0.076 g a.i. L^{-1}; (T_5) AVG at 0.15 g a.i. L^{-1} twice at each seven days; (T_6) 1-MCP sprayed at 0.076 g a.i. L^{-1} twice using the same interval and (T_7) AVG at 0.15 g a.i. L^{-1} plus 1-MCP at 0.076 g a.i. L^{-1} twice at each seven days. Error bars represent the standard errors of four plants, each representing a replication.

Aiming to uncover the inhibitor effects on some treatments, orthogonal contrasts were constructed. In terms of boll dry mass, except for third reproductive branch, all ethylene inhibitor treatments (T_2; T_3; T_4; T_5; T_6 and T_7) improved the performance, independently of the mode of action of the compounds or entries number, when compared to those untreated control (Table 1).

Table 1. Estimate of the orthogonal contrasts relative to the boll dry weight across of the reproductive branch sprayed with ethylene inhibitors

Contrast at first reproductive branch			**Boll dry weight $_{estimate}$**	**Pr > |t|**
$\hat{Y}_1$ = T2, T3, T4, T5, T6 and T7	vs.	T1	4.06	**0.000**
$\hat{Y}_2$ = T3	vs.	T6	5.20	**0.000**
$\hat{Y}$3 = T2	vs.	T5	1.49	0.845
$\hat{Y}$4 = T7	vs.	T4	8.10	**0.000**
$\hat{Y}$5 = T2	vs.	T3	2.44	**0.043**
$\hat{Y}$6 = T6	vs.	T5	4.25	**0.001**
Contrast at second reproductive branch			**Boll dry weight $_{estimate}$**	**Pr > |t|**
$\hat{Y}_1$ = T2, T3, T4, T5, T6 and T7	vs.	T1	3.39	**0.000**
$\hat{Y}_2$ = T3	vs.	T6	5.34	**0.000**
$\hat{Y}$3 = T2	vs.	T5	1.80	0.153
$\hat{Y}$4 = T7	vs.	T4	11.15	**0.000**
$\hat{Y}$5 = T2	vs.	T3	3.34	**0.006**
$\hat{Y}$6 = T6	vs.	T5	0.20	0.869
Contrast at third reproductive branch			**Boll dry weight $_{estimate}$**	**Pr > |t|**
$\hat{Y}_1$ = T2, T3, T4, T5, T6 and T7	vs.	T1	1.36	0.139
$\hat{Y}_2$ = T3	vs.	T6	-3.62	**0.003**
$\hat{Y}$3 = T2	vs.	T5	1.38	0.059
$\hat{Y}$4 = T7	vs.	T4	3.62	**0.003**
$\hat{Y}$5 = T2	vs.	T3	3.57	**0.003**
$\hat{Y}$6 = T6	vs.	T5	3.73	**0.002**
Contrast at fourth reproductive branch			**Boll dry weight $_{estimate}$**	**Pr > |t|**
$\hat{Y}_1$ = T2, T3, T4, T5, T6 and T7	vs.	T1	1.93	**0.033**
$\hat{Y}_2$ = T3	vs.	T6	0.03	0.980
$\hat{Y}$3 = T2	vs.	T5	8.48	**0.000**
$\hat{Y}$4 = T7	vs.	T4	2.23	0.064
$\hat{Y}$5 = T2	vs.	T3	7.12	**0.000**
$\hat{Y}$6 = T6	vs.	T5	1.33	0.267
Contrast at fifth reproductive branch			**Boll dry weight $_{estimate}$**	**Pr > |t|**
$\hat{Y}_1$ = T2, T3, T4, T5, T6 and T7	vs.	T1	2.67	**0.004**
$\hat{Y}_2$ = T3	vs.	T6	0.44	0.136
$\hat{Y}$3 = T2	vs.	T5	7.72	**0.000**
$\hat{Y}$4 = T7	vs.	T4	-1.90	0.114
$\hat{Y}$5 = T2	vs.	T3	-2.71	**0.025**
$\hat{Y}$6 = T6	vs.	T5	4.57	**0.000**
Contrast at sixth reproductive branch			**Boll dry weight $_{estimate}$**	**Pr > |t|**
$\hat{Y}_1$ = T2, T3, T4, T5, T6 and T7	vs.	T1	-4.68	**0.000**
$\hat{Y}_2$ = T3	vs.	T6	2.95	**0.015**
$\hat{Y}$3 = T2	vs.	T5	2.86	**0.018**
$\hat{Y}$4 = T7	vs.	T4	5.97	**0.000**

$\hat{Y}5 = T2$	vs.	T3	-4.27	**0.000**
$\hat{Y}6 = T6$	vs.	T5	1.55	0.197
Contrast at seventh reproductive branch			**Boll dry weight $_{estimate}$**	**Pr > |t|**
$\hat{Y}_1$ = T2, T3, T4, T5, T6 and T7	vs.	T1	2.50	**0.007**
$\hat{Y}_2 = T3$	vs.	T6	2.90	**0.017**
$\hat{Y}3 = T2$	vs.	T5	-1.69	0.159
$\hat{Y}4 = T7$	vs.	T4	3.94	**0.001**
$\hat{Y}5 = T2$	vs.	T3	0.93	0.437
$\hat{Y}6 = T6$	vs.	T5	2.14	0.076

Treatments consisted of application of (T_1) control, where only deionized water was sprayed; (T_2) sprayed with AVG at 0.15 g a.i. L^{-1}; (T_3) 1-MCP at 0.076 g a.i. L^{-1}; (T_4) AVG at 0.15 g a.i. L^{-1} plus 1-MCP at 0.076 g a.i. L^{-1}; (T_5) AVG at 0.15 g a.i. L^{-1} twice at each seven days; (T_6) 1-MCP sprayed at 0.076 g a.i. L^{-1} twice using the same interval and (T_7) AVG at 0.15 g a.i. L^{-1} plus 1-MCP at 0.076 g a.i. L^{-1} twice at each seven days. Means followed by the same letter are not significantly different at the $p < 0.05$ level by Student's statistical tests (LSD).

At least for first and second sympodial branch, the combination of ethylene inhibitor action and its synthesis sprayed twice at each seven days (AVG at 0.15 g a.i. L^{-1} plus 1-MCP at 0.076 g a.i. L^{-1} - T_7) showed higher performance for boll dry mass whether compared to the same combination and doses sprayed one time (T_4). On the other hand, the application of 1-MCP at 0.076 g a.i. L^{-1} (T_3) one time showed better performance than the same dose sprayed twice at each seven days (T_6) for this same first sympodial branch. Although there were not significant differences for three first reproductive branch for entries number relative to AVG at 0.15 g a.i. L^{-1} (T_2 and T_5) treatments, from the fourth reproductive branch the application of the same treatment with additional entry resulted in a significant increase in boll dry mass.

4. Discussion

Concerning to LWPpred different authors found a linear or near linear declines in cotton leaf and whole canopy photosynthesis (*P*n) with LWPpred decrease (Ackerson et al., 1977; Parsons et al., 1979; Marani et al., 1985). In all cases, the decline in *P*n was well established by the time LWPpred had dropped to -1.2 MPa with near 50% of Pn reductions when LWPpred reached -1.9 MPa. In this report, gas exchange analysis of untreated control with Ethylene inhibitors and submitted to stress showed a significant photosynthesis decline at the end of stress period. As has been established (Centritto et al., 2009) stomatal resistance can progressively reduce the CO_2 concentration reaching the chloroplasts. Similarly, it was observed for photosynthesis, stomatal conductance and transpiration rate across ethylene inhibitor treatments and stress levels, where reductions there were linear for these parameters across the stress level, showing that photosynthesis was limited by declining *g*s, although a concomitant *g*s adjustment to the drought-induced inhibition of photosynthetic rate cannot be ruled out (Wong et al., 1979). There is an indication that, at least to -1.1 MPa of leaf water potential, there were probably no lasting metabolic limitations to photosynthesis in response to the different ethylene inhibitor treatments and its combinations.

Analyzing the effects of ethylene inhibitors on cotton boll dry mass, is necessary to consider that cotton yield is determined by combination of many yield components, including boll number, boll size, seed number per boll and fiber cell per seed. All these components can be influenced by plant physiological activity and its environment interaction. In this report, the inhibition of ethylene action and/or its synthesis were able to increase its boll dry mass when submitted to water deficit. As has been established by different studies, under abiotic stress cotton plants alters the hormone balance and triggers the activation of pathways involved in these responses, resulting in the abscission of squares and bolls consequently reducing the seed cotton yield and fiber yield (Stewart et al., 2010; Brito et al., 2013). As above described, a common response of cotton plants when submitted to stress is its increased ethylene biosynthesis; and although this comportment is very well established and its role in the regulation of the abscission process in cotton fruit is extensively reported, the relationship of ethylene with boll dry mass across of the reproductive branches via positional plant mapping and its photosynthetic responses to water deficit is scarce. In this study, the results demonstrated that ethylene inhibitor application can sustain higher cotton boll dry mass accumulation when these plants are submitted to water deficit whether compared to those untreated. In this sense, recently studies are showing the role of ethylene in

carbohydrate balance and its metabolism (Albacete et al., 2014; Carreno-Quintero et al., 2013; Deng et al., 2013). As sucrose is the major form of carbohydrates transported from photosynthetically active source to non-photosynthetic sinks such as reproductive structures and roots, here including flowers and cotton bolls in development, any stress can triggers plants responses to alter this source:sink relation. In this context, has been showed the role of ethylene on key enzymes named as cell wall invertase that hydrolyses sucrose to glucose and fructose which could have preponderant role in this response. Additionally, have been showed the influence of ethylene levels on invertase activity; where increase ethylene biosynthesis has been associated in a decrease of invertase activity varying from 25 to 47% when compared those cells maintained under control treatment (Mirjalili & Linden, 1996; Linden et al., 1996); yet should be considered that cell wall invertase is not only involved in providing carbon nutrients to plants but also plays major roles in sugar signaling and development as demonstrated by Ruan and co-workers (Ruan et al., 2010). In this context, the ethylene inhibition synthesis or action could allow to cotton plants sustain higher level of cell wall invertase activity what could help to explain those higher values found for boll dry mass in cotton submitted to water deficit.

The occurrence of a water deficit, particularly during the reproductive phase, can negatively impact the physiology, growth and yield of the cotton crop (Stewart et al., 2010; Ullah et al., 2008; Brito et al., 2014). In general, this report demonstrates that the ethylene inhibitor applications can mitigate the effects of water deficit on important components yield, such as boll dry mass and total boll per plant, even ethylene inhibitors effects was stronger in boll dry mass compared to boll number. Although the role of ethylene on cotton plants and its interaction with key enzymes, such as sucrose synthase and invertase is not fully understood, positive effects of 1-MCP (Kawakami et al., 2010) and 1-MCP and AVG (Brito et al., 2013) on the physiology and yield of field-grown cotton were demonstrated. When 1-MCP was sprayed during the first flower emission phase on plants submitted to water deficit, there were inhibition of cotton stress response, as evidenced by the low antioxidant activities and higher quantum yield, with consequent increase in the boll weight and seed number per boll. Similarly, AVG treatment positively impacted on seed cotton yield and this effect resulted from changes in the boll number which, in turn, may have been caused by differences in the level of fruit abscission and due to the changes in ethylene synthesis in cotton plants submitted to water deficit. Additionally, in our report, this ethylene inhibition could explain the higher values for cotton boll dry mass found in plant treated with ethylene inhibitors, what could sustain the sink strength due a possible high activity of enzymes involved in carbon metabolism.

Our results not only emphasize the potential role of ethylene mediating the response of cotton plants to environmental stressors but also demonstrate the effects of the ethylene inhibitors on the negative impacts of this hormone on cotton yield components. As there is a consensus that the primary driving force for natural shedding is the source/sink imbalance, which determines the relative rates of production and transport of various hormones in the plant which, in turn mediate developmental delays (Baker & Baker, 2010), new studies to evaluate physiological and biochemical variables are necessary to elucidate the mechanisms involved in the response of cotton plants sprayed with ethylene inhibitors; particularly enzymes involved in carbon metabolism in cotton plants submitted to water deficit. More research is required to understand the physiological roles of ethylene and ethylene inhibitors on key enzymes involved in the carbohydrates metabolism aiming clear the results found in this study. In addition, more detailed investigations are required into the practicality and costs to applying these compounds as a commercial management practice when the risk of imminent environmental stress in the cotton production Brazilian region is known.

5. Conclusions

The 1-MCP and AVG compounds sprayed solely or in combination in first flower emission are able to reduce the negative consequences of environmental stressors on photosynthesis, total boll number and boll dry mass across of the sympodial branches suggesting that cotton ethylene production may play a significant role in its yield performance.

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