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Plant Growth Reducers: An Alternative to Increase the Juice Production Potential and Decrease the Lodging of Sweet Sorghum

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Abstract: The plant growth regulators can improve the crop performance, making the plant architecture more adapted and efficient in order to use environmental resources and inputs to support the high-yielding agronomic traits. The objective of this study was to evaluate the effects of three growth reducers on the sweet sorghum development. The experimental design was completely randomized with four treatments and eight replications. The treatments were control (water), maleic hydrazide 1.44 g a.i. L^{-1}, paclobutrazol 1.5 g a.i. L^{-1} and chlormequat 0.5 g a.i. L^{-1}. The sorghum development was evaluated by biometric parameters, relative chlorophyll content and potential of juice production. All growth regulators decreased the growth rate of sorghum, resulting in the height reduction (20.56 to 33.94% compared to control). These compounds also increased the relative chlorophyll content (22.15 to 29.54%), but did not change the fresh and dry mass of shoot. Furthermore, the juice production potential was increased after application of chlormequat and paclobutrazol (2.72 to 4.56% in relation to control). These results indicate that growth reducers can be used as an alternative to decrease the lodging and increase the juice production of sweet sorghum 'Ceres 81'.

Key words: *Sorghum bicolor* · Growth retardants and inhibitors · Plant architecture · Initial development

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] has occupied many agricultural areas in Brazil, mainly due to its tolerance to drought and sprouting capacity, allowing high yields per unit area [1]. It can be used in animal nutrition, since sorghum has a high dry matter yield and nutritional value [2]. It can also be utilized for ethanol production, due to its fast cycle, easy mechanization and high content of directly fermentable reducing sugars in the stem [1]. However, many sorghum cultivars are tall and prone to lodging, causing serious losses to producers [3]. In order to minimize the lodging, the sorghum should be cultivated with an appropriate planting density for each cultivar [1]; however, another alternative is the use of plant growth regulators.

The plant growth regulators are compounds that act as chemical signals, controlling the plant development. They normally bind to receptors in the plant, triggering a series of cellular changes, which may affect the initiation or modification of tissues and organs [4]. The growth reducers are compounds that change several plant characteristics, reducing the leaf area and increasing the chlorophyll content, leaves thickness and root growth. However, morphological changes are accompanied by modifications in the plant physiology and development [5] and studies are needed to generate information about the implications of the growth reducers in crops. The objective of this study was to evaluate the effects of three growth reducers on the sweet sorghum 'Ceres 81' during the vegetative growth period.

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Table 1: Maximum, minimum and average temperature, rainfall average amount and relative humidity, from December 2011 to February 2012 at the experimental area.

	Monthly average temperature (°C)				
Month	Maximum	Minimum	Average	Rain amount (mm)	Relative humidity (%)
December	30.5	18.4	24.5	176.1	73
January	28.9	18.2	23.6	217.0	82
February	32.6	19.8	26.3	139.2	73

Values are the means of 8 replications ± standard error. Same letter do not differ by Tukey test at 5% among treatments, within each evaluation period (days after foliar spray). Significance: *** p <0.001; and ns: not significant.

Table 2: Growth reducer effects on the relative chlorophyll content, fresh mass and dry mass of shoots and the potential of juice production.

	Parameters			
Treatments	Chlorophyll content (SPAD)	Fresh mass of shoots (g)	Dry mass of shoots (g)	Juice production (%)
Control	28.03 ± 1.09 b	182.85 ± 19.79 a	32.96 ± 3.53 a	81.96 ± 0.36 b
Maleic hydrazide	34.24 ± 1.49 a	153.21 ± 9.11 a	25.77 ± 2.04 a	83.28 ± 0.59 ab
Chlormequat	36.31 ± 1.06 a	194.08 ± 11.29 a	31.00 ± 1.36 a	83.90 ± 0.39 a
Paclobutrazol	35.06 ± 1.26 a	161.90 ± 11.42 a	24.35 ± 2.00 a	85.02 ± 0.51 a
Coefficient of variation (%)	$10{,}47^{***}$	$22{,}13^{ns}$	$23{,}51^{*}$	$1{,}59^{***}$

Values are the means of 8 replications ± standar error; means followed by same letter do not differ by Tukey test at 5% of probability. Significance: *** p=0.001, * p=0.05 and ns: not significant.

MATERIALS AND METHODS

The experiment was carried out under environmental conditions, at ''Luiz de Queiroz'' College of Agriculture in Piracicaba, SP, Brazil, (22° 42'S and 47° 38' W) from December 2011 to February 2012. Weather data during the experimental period was recorded (Table 1).

Sweet sorghum seeds cultivar Ceres 81 were placed in plastic containers (15 dm^3) which were filled with a mixture of clay, silt and sand (2:1:1), respectively; 10 days after planting (DAP), a homogenous adjustment was made to ensure that only two seedlings remained in each pot. The experimental design was completely randomized with four treatments and eight replications. The treatments were: a) control (water), b) maleic hydrazide 1.44 g a.i. L^{-1}, c) paclobutrazol 1.5 g a.i. L^{-1} and d) chlormequat 0.5 g a.i. L^{-1}, which were applied through foliar sprays 28 DAP.

The plant height was provided by the distance between the stem base and the insertion of the last leaf in the upper portion, which have been evaluated weekly, from 33 to 47 DAP (time corresponding from 5 to 19 days after foliar spray). The shoot was collected in order to determine the fresh mass 47 DAP, then packed in paper bags and taken to an oven (for 72 h at 60 °C), to obtain the shoot dry mass. The potential of juice production was estimated from the percentage of liquid found in the shoot fresh mass, by the equation (1):

$$JP = 100 - (DM \times FM) \times 100 \quad (1)$$

Were JP is the juice production, DM is the dry mass of the shoot and FM is the dry mass of the shoot.

The chlorophyll content was measured by chlorophyll meter Minolta SPAD-502, in two points of newly expanded leaf and outside the central rib area, 40 DAP. The height and relative chlorophyll content were obtained from the arithmetic mean of the values found in two plants of each pot.

The data obtained were subjected to analysis of variance (ANOVA) at 5% significance level, through the SAS® statistical software [6]. The repeated measures analysis was used to evaluate the effects of treatments on the plant height during the experimental period. Tukey test was used to estimate the least significant range among means (α=0.05) and a regression analysis was performed to evaluate the effect of each growth reducer during such time. The height data were changed into x =1/height to be according to statistical assumptions to perform the ANOVA test. After analysis, data were converted back to the original scale, to facilitate comparison of results among treatments.

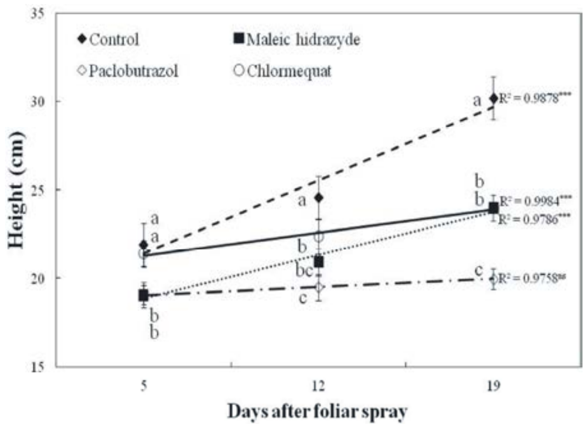

Fig. 1: Growth reducer effects on the sorghum plants throughout the experimental period.

RESULTS AND DISCUSSION

The growth reducers affected significantly the plant height, the relative chlorophyll content and the potential of juice production. However, the fresh and dry mass of shoots in the treated plants was not changed, when compared to control.

There was non-significant height increase in the plants treated with paclobutrazol, showing the high efficiency of this ompound regarding the growth inhibition of the sweet sorghum ‘Ceres 81’, a height reduction of 33.94% in comparison to control, at the final evaluation (Fig. 1).

The growth reduction occurs because paclobutrazol inhibits the gibberellins biosynthesis, which is hormones responsible for cell expansion [5]. The chlormequat chloride also inhibits gibberellin biosynthesis, however it acts more efficiently after a time longer than the paclobutrazol does, which explains the height difference between these two treatments. Probably this difference is due to the paclobutrazol blocks the activity of an enzyme distinct from that inhibited by chlormequat [5].

Plants treated with maleic hydrazide also showed height lower than control at the final evaluation (20.56%), however this compound affected the plant growth less aggressively than other treatments (Fig. 1). The maleic hydrazide reduces the plant height by inhibition of both mitosis and meiosis in meristematic regions [7, 8]. Probably, cell division inhibition is because this compound interferes in the spindle fibers formation [9]; however it does not act on the cell elongation [7].

The height reduction of tall cultivars is relevant, since it causes a decrease in production costs due to decreased manpower used during cutting and field losses [3]. Although lodging is not a major limiting factor of sorghum crop, some cultivars showed high incidence of lodging, from 22.0 to 55.8% [3]. Therefore, alternatives which allow the cultivation of these genotypes are important.

The growth reducers did not affect fresh and dry biomass of shoot in relation to control, despite the height reduction of the sorghum plants.

Probably this result is related to the significant increase in the relative chlorophyll content in plants treated with growth reducers (increases from 22.15 to 29.54% compared to control) that may have higher photosynthetic efficiency. Chlorophyll is a pigment directly associated with the photosynthetic activity, which is responsible for the conversion of sunlight into chemical energy in the form of ATP and NADPH [4], favoring the fixation of atmospheric carbon dioxide and providing thereby the production of plant biomass.

The paclobutrazol and chlormequat chloride also increased the potential of juice production, which may favor the ethanol production because, according to Giaciomini (1979) [10], cultivars of sweet sorghum must submit, among other features, a high percentage of juice extraction for high ethanol production.

CONCLUSIONS

It is concluded that growth reducers can be an alternative to decrease the lodging and increase the juice production of sweet sorghum 'Ceres 81'.

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