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Full Length Research Paper

Sunflower seed treatment with growth inhibitor: Crop development aspects and yield

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Sunflower is one of the most important oleaginous crops designated for edible oil production in the world. However, Brazilian growers still do not have enough knowledge, and technical expertise, for expanding the sunflower crop yield through the adoption of new technologies, like the utilization of plant growth regulators (paclobutrazol). The aim of this work was to evaluate the effects of different doses (0, 50, 100, 150 and 200 mL ha^{-1}) of the growth regulator paclobutrazol on agronomic characteristics of sunflower crop in Uberlandia, Minas Gerais State, Brazil. Treating the seed with paclobutrazol decreased the size of the disk flowers and the plant height, while the number of days to complete the development cycle increased. The yield was not affected by the different doses. The use of paclobutrazol in seed treatment is an interesting tool to manage the development of the sunflower crop, as it affects desirable parameters which does not reduce seed yield.

Key words: *Helianthus annuus* L., paclobutrazol, biorregulator.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the main oleaginous crops designated for edible oil production in the world. In the 2014/2015 agricultural year, a yield of 1,376 kg ha^{-1} was reached in Brazil, resulting from 109.4 thousand hectares cultivated with this crop (CONAB, 2015).

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Considering the higher resistance to heat, drought and cold than most of the species grown in Brazil (Lima et al., 2014), sunflower areas expanded with about 25% in 2014/2015 as compared to the agricultural year of 2013/2014 (CONAB, 2015). This crop has received more attention due to its good results as an option to succession planting and crop rotation, animal feed, honey production and functional human nutrition (Faria et al., 2015; Ungaro et al., 2009). Furthermore, since 2010, the Brazilian government demands that all diesel commercialized in Brazil should be admixed with at least 5% of biodiesel (Matsumoto et al., 2015).

Even with the increasing demand of this product, Brazilian production is still low, for example only 1.5 Russian production, and is about half of the Israeli average yield (FAO, 2015). Growers in Brazil still do not have enough experience with sunflower; neither have capacitated technical assistance to expand the yield of this crop. One example of applicable technology is the utilization of plant hormones and growth regulators, which is insufficiently explored in this crop (Spitzer et al., 2011)

One of the currently used plant growth regulators in agriculture is paclobutrazol. This compound is a triazole derivative known for its inhibitory activity against sterol and gibberellin synthesis (Rademacher, 2000; Khan et al., 2009). It affects some aspects of the plant such as height and flowering, due to alterations in phytohormone levels (Kim et al., 2012). These modifications are interesting for sunflower production due to the high susceptibility of this crop to lodging, which is correlated to its considerable height and weight of its disk flower (Sposaro et al., 2008).

However, its results depend on the applied concentrations, number, the moment of applications, and target (foliar or soil) (Almeida And Pereira, 1996; Koutoubras et al., 2014). Furthermore, there are just a few studies on the use of paclobutrazol in seed treatment (Melo et al., 2014, 2015). Due to these facts, the utilization of this hormone in the sunflower crop still requires more studies.

The aim of this work is to evaluate the effects of different doses of seed treatment with paclobutrazol in agronomic characteristics related to the sunflower crop production in Uberlandia, Minas Gerais State, Brazil.

MATERIALS AND METHODS

This work was conducted in 2015 at an experimental area in Heliagro Agricultura e Pecuária (24°20'32'' S; 53°51'36'' W), located in Uberlandia, Brazil. The region has an average altitude of 830 m and weather classified as Aw according to Köppen classification and it is considered a tropical wet climate but with a pronounced dry season (Ribeiro et al., 2013).

It was established as a randomised block design, with five replications for each treatment. The treatments were based on different doses of paclobutrazol: 0 (Control), 50, 100, 150 and 200 mL ha^{-1}. Each plot consisted of four rows of six meters with a space of 0.7 m from the other, comprising 80 plants each one; the distance between plots was 1 m.

The paclobutrazol solution was obtained from a commercial product registered as Cultar 250 SC. The different doses were applied inside a plastic bag with the seeds, followed by intense agitation for good coverage of the seeds. The chosen variety of sunflower was the simple hybrid Helio 251, recommended for all the Central Brazilian territory (Porto et al., 2008)

The sowing was in March manually and jab "matraca" planter was used. After emergence and initial development of seedlings, some of them were removed to avoid intraspecific competition and to establish a population of 45,000 plants ha^{-1}.

During sowing, 350 kg ha^{-1} of the fertilizer 8-20-20, related to the concentrations of nitrogen, phosphorus and potassium, respectively, was applied in the furrows. Twenty days after the crop emergence, there was a side dressing fertilization with 150 kg ha^{-1} of ammonium nitrate. Also, there were applications of 10 kg ha^{-1} of sodium octaborate, diluted in water and applied to the soil while sowing and ten days after the crop emergence. The fertilization was based on soil fertility analysis to meet the nutritional requirements of the crop described by Ribeiro et al. (1998).

For the evaluations, only the two central rows of each parcel were considered. The height of the plants was measured from the soil to the upper leaf at flowering (considering 50% of the plants with 50% open flowers). The average size of the disk flowers was assessed at harvesting by measuring the length between the extremities of the structure. After the manual harvest, the achenes were taken to the laboratory to be separated from the seeds, which were weighted to determine the production of each parcel and from those results, the estimated yield (kg ha^{-1}) was calculated.

The results were submitted for normality test of residuals (Shapiro-Wilk test) and homogeneity of variance (Bartlett test) using the SPSS software. The variance analysis was assessed using F-test with 5% significance variance analysis. The choice of the regression model was based on the significance of the regression coefficients and on the highest value of the determination coefficient; in both cases, the SISVAR (Ferreira, 2011) software was used.

RESULTS AND DISCUSSION

The sunflower plants presented distinct results in response to the different doses of paclobutrazol in the following characteristics: size of the disk flowers, height of the plants and duration of the productive cycle (Table 1). However, the weight of the grains after the harvest did not present any differences due to the treatments. The biggest disc flowers were observed with 50 mL ha^{-1} dose of paclobutrazol, followed by the dose of 100 mL ha^{-1}, while the higher doses gave similar or even lower results as compared to the control (Figure 1).

This occurred because gibberellins have an inhibitory effect on the flowering process (Pereira et al., 2014). As paclobutrazol inhibits the synthesis of this hormone in plants and interfer with the oxidation of ent-kaurene to

Table 1. Variance analysis table for development and yield parameters of sunflower under different doses of paclobutrazol in seed treatment.

Sources of variance	DF	DD	SY	HP	DC
Treatments	4	4.06*	0.06^{NS}	0.03*	26.06**
Block	4	1.76^{NS}	0.08^{NS}	0.01^{NS}	1.66^{NS}
Residue	16	0.98	0.06	0.01	3.63
VC		5.16	28.48	5.22	2.47

VC: Variation coefficient; DF: degree of freedom; DD: diameter of the disk flower; SY: seed yield; HP: height of plants; DC: days to complete the development cycle. Values followed by NS were not significant at 5% of significance; *Significant at 5%; **significant at 1%.

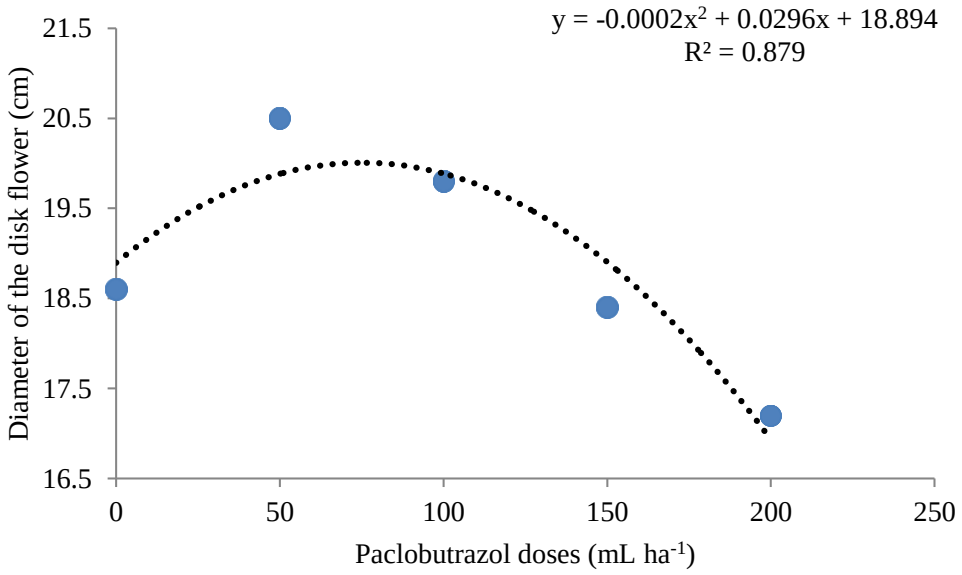

Figure 1. Size of the disk flowers under an increasing dose of paclobutrazol in sunflower seed treatment.

kaurenoic acid in the pathway of gibberellins (Almeida and Pereira, 1996; Zheng et al., 2012), lower doses of this growth inhibitor might be beneficial to the flowering development of several crops. However, higher doses have a negative effect on this parameter, as also observed by Wanderley et al. (2007), who noticed that high doses of paclobutrazol resulted in smaller disc flowers in sunflower under the hydroponic system.

The height of the plants at flowering showed a concentration dependence following paclobutrazol treatment (Figure 2). The control treatment had the highest average plant height (1.89 cm), while the treatments with paclobutrazol presented lower values.

Wanderley et al. (2014) noticed that in ornamental sunflower produced in a hydroponic system, the reduction of the height reached even 90%, while Koutoubras et al. (2014) reported a decrease of 11.1%. So it is important to highlight that different genotypes of sunflower might present variable responses to paclobutrazol. Lower plant growth resulting from the utilization of paclobutrazol was also reported in several other crops (Hua et al., 2014; Peng et al., 2014; Koutoubras and Damala, 2015). Gibberellin promotes stem growth, especially as a result of its effect on cell elongation (Zhang et al., 2011; Yang et al., 2012). By inhibiting gibberellins, paclobutrazol also reduces the plants' height. This is a very desirable result for the sunflower crop as tall plants and heavy discs make plants

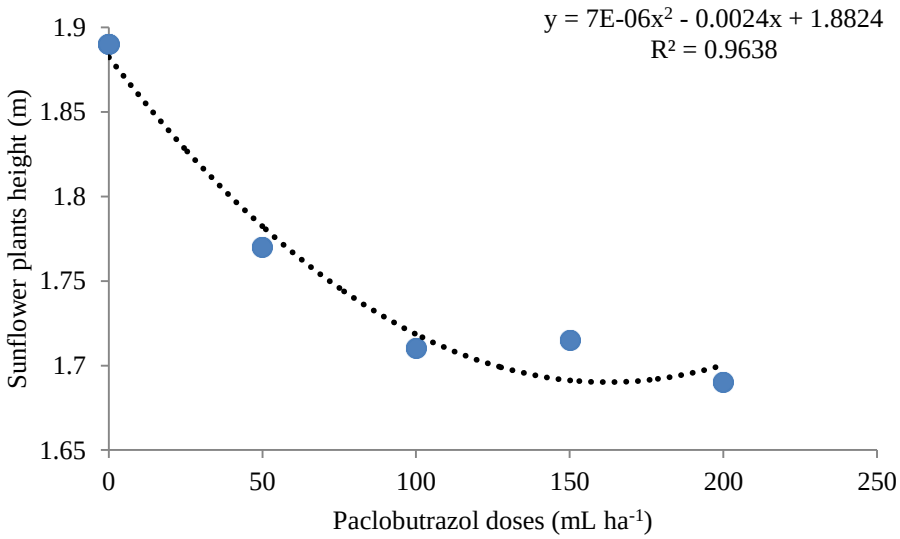

Figure 2. Average height of sunflower plants at flowering under increasing doses of paclobutrazol in seed treatment.

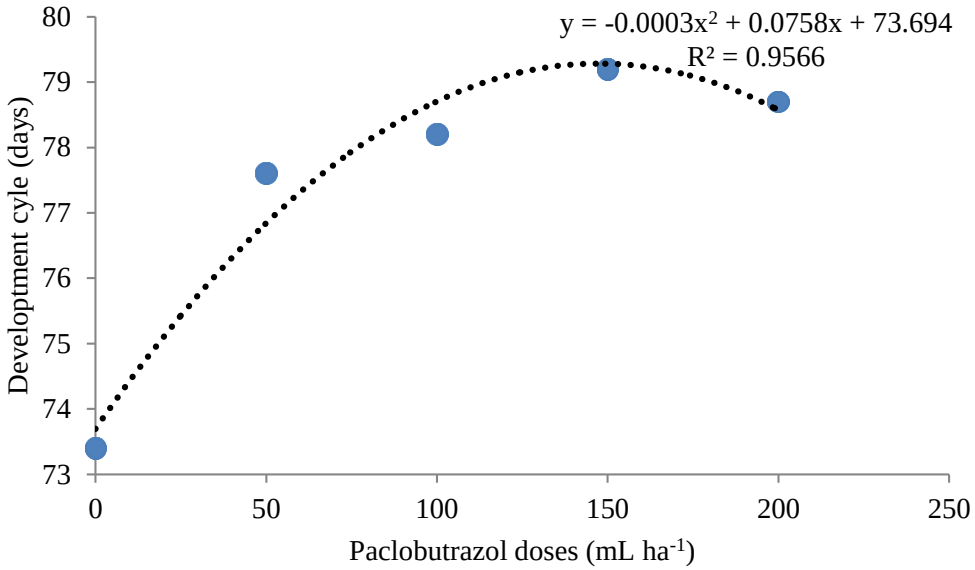

Figure 3. Number of days from sowing to physiological maturity of sunflower plants under increasing doses of paclobutrazol in seed treatment.

very susceptible to lodging (Koutoubras et al., 2014; Silva et al., 2015). This way, shorter sunflower plants might be a strategy to reduce losses in the mechanized harvest.

Seeds treated with paclobutrazol need longer time to complete development, in some cases almost an additional week (Figure 3). Thus, the treatment without paclobutrazol was faster in reaching the physiological maturity. This might be related to a delay in the emergence of the shoots caused by the growth inhibitor. Melo et al. (2014) noticed that tomato seeds treated with

paclobutrazol had a reduced germination rate and seedling emergence; this is related to the antagonizing effect of gibberellin, which is an essential hormone to germination.

Another reason for the longer cycle is the delayed development of leaf primordia into expanded leaves. This result was reported by Almeida and Pereira (1996), while assessing foliar applications of paclobutrazol in sunflower crop. With a smaller quantity of expanded leaves, photosynthesis is less effective, indicating a longer time for the plant to complete its vegetative cycle.

A longer productive cycle can be a problem for Brazilian conditions. In this country, sunflower is usually produced in the same fields after another crop such as soybean in the same year. With a higher amount of days in the field, the plants are more exposed to aggressive diseases like white mold (Markell et al., 2015) and weather conditions like wind damage. The results show an undesirable effect of the growth inhibitor in this regard, implying that the use of paclobutrazol in seed treatment should be followed by rigorous phytosanitary strategies.

The seed yield did not show any statistical differences between the treatments (Table 1). The average yield was relatively low (1044.92 kg ha^{-1}) when compared with the Brazilian average yield (FAO, 2015), but this is the consequence of an unexpected drought in the area during the experiment. The yield responses found in this study were similar to those found by Koutoubras et al. (2014), who reported that a single foliar application of paclobutrazol resulted in shorter plants, but without the detriment of any yield parameters, like seed weight or number of achenes per disk flower.

However, paclobutrazol also increases yield in other crops (Tekalign and Hammes, 2005; Hua et al., 2014; Gatan and Gonzalez, 2015). This indicates that paclobutrazol might be a valuable tool for sunflower production as a growth regulator, as it reduces plant height and does not negatively affect yield. However, as it causes a longer development cycle, further researches involving environmental factors (as diseases occurrence) are needed for a clearer conclusion on the potential of this tool.

Conclusions

The use of paclobutrazol in seed treatment might be an interesting tool to manage the development of the sunflower crop under propitious conditions for plant lodging, as it reduces height without affecting seed yield. More studies are necessary to evaluate if the longer time to complete the development cycle can be harmful to sunflower in the presence of abiotic or biotic stresses.

Conflict of Interests

The authors have not declared any conflict of interests.

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