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Growth and productivity of soy plants treated with benzyladenine

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Abstract: The high percentage of soybean plant flower and pod abortion impairs grain productivity. Flower and pod setting mechanisms have not yet been fully understood. Hormonal balance is believed to have important influence on the flower and pod set rate. Therefore, the present study was designed to evaluate the effects of benzyladenine in the abortion of reproductive structures and in the productivity of soybean plants. The work was conducted in the town of Ipameri, Goiás, Brazil. The region features humid tropical climate, with rainy summers and dry winters. The soil in the experimental area was classified as Oxissol. After soil analysis, fertilization and pH correction were accomplished. The sowing of Pioneer 98Y12 RR soybean was carried out in mid-November during the rainy season. Five different kinds of treatment with 0, 100, 200, 300 and 400 mg L^{-1} of benzyladenine were used, applied during the V_6 stage, at the 200 L ha^{-1} spray volume. The experiment was conducted following the randomized block design with five replications. The experimental area was 3x2 m and about 90 plants were researched in 0.5 m spaced rows with 10 plants per linear meter. The application of benzyladenine reduced pod abortion and increased the productivity of soybean plants, for which they adapted morphologically and physiologically to optimize solar radiation capture and increase the production of assimilates. The application of benzyladenine is a promising practice in soybean culture management.

Key words: Hormones, Grain yield, Production physiology.

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Crescimento e produtividade de plantas de soja tratadas com benziladenina

Resumo: O elevado percentual de abortamento de flores e vagens em plantas de soja compromete a produtividade de grãos. Os mecanismos de fixação de flores e vagens não se encontram completamente esclarecidos. Acredita-se que o balanço hormonal exerça importante influência na taxa de fixação de flores e vagens. O presente estudo teve como objetivo avaliar os efeitos da benziladenina no abortamento de estruturas reprodutivas e produtividade de plantas de soja. O trabalho foi conduzido no município de Ipameri, Goiás, Brasil. Esta região possui clima tropical úmido, com verão chuvoso e inverno seco. O solo da área experimental é classificado como Latossolo Vermelho-Amarelo. Após a análise do solo, foi realizada a adubação e correção do pH. A semeadura da soja Pioneer 98Y12 RR foi realizada em meados de novembro durante o período da estação chuvosa. Foram utilizados cinco tratamentos com 0; 100; 200; 300 e 400 mg L^{-1} de benziladenina aplicados na fase V_6, no volume de calda de 200 L ha^{-1}. O experimento foi montado seguindo o delineamento em blocos casualizados com cinco repetições. A parcela experimental foi de 3 x 2 m e cerca de 90 plantas exploradas em espaçamento de 0,5 m entre linhas e 10 plantas por metro linear. A aplicação de benziladenina reduziu o abortamento de vagens e aumentou a produtividade de plantas de soja, para tal, a planta ajustou-se mofologicamente e fisiologiamente para otimizar o uso da radiação solar e aumentar a produção de assimilados. A aplicação da benziladenina representa prática promissora de manejo da cultura da soja.

Palavras chave: Hormônio, Rendimento de grãos, Fisiologia da produção.

Introduction

Soybean is of great importance for the Brazilian economy by generating direct jobs in crops and indirect in the sale of inputs in several regions (Almeida, 2017). The main producing states are Mato Grosso, Paraná, Rio Grande do Sul and Goiás with 26.74%, 17.12%, 16.40% and 9.5% of the national production respectively. Brazil is the world's second largest producer of soybeans with production in the 2016/17 crop of 114,095 million tons and productivity of 3,362 kg ha^{-1} National Supply Company [CONAB] (2017). The increase in soybean production can be attributed to the high protein content (around 40%) of excellent quality for animal and human food and a considerable oil content in the seeds (around 20%) that can be used for several especially for human consumption and the production of biofuels (Borges et al., 2014). Soybeans and corn make up 85% of animal feed rations in Brazil, and about 80% of biodiesel produced in the country has soybeans as raw material (CONAB, 2017 & Brasil, 2017).

Brazil has one of the most extensive agricultural areas in the world, with capacity to expand the cultivation of this oilseed to meet the demand for food and biofuels (YU et al., 2013). However, the expansion of cultivated areas has faced challenges, such as the stalemate on environmental issues related to deforestation and consequent environmental impacts, such as greenhouse gas emissions and biodiversity losses. (Lazzarotto & Hirakuri, 2010).

It can be noticed that the increase of production occurs exclusively due to the increase of the planted area without significant increase in the production per hectare. The increase in production was perceived to be due solely to the increase in planted area, with no significant increase having been seen in the production per hectare. The same situation also occurred in the global scenario, where according to State Secretariat for Agriculture and Food Supply [SEAB] (2013) in the 2012/2013 harvest there was a production of 267,606 million tons in an area of 108.69 million hectares with an average production of 2,460 kilograms per hectare. And in the 2013/2014 harvest, production increased to 285,304 million tons, but this increase was exclusively due to an expansion of the planted area, which was 111.58 million hectares, since the average productivity was similar to the previous harvest, 2,540 kilograms per hectare, not coming to a 1%-increase. It has become necessary to develop management practices that can increase the productivity of soybean plants, because the expansion of explored areas is limited by environmental protection laws designed to protect a minimum of natural vegetation on the earth's surface.

The use of artificial growth regulators has been steady in agriculture because they increase agricultural productivity and play an essential role in plant metabolism. Studies indicate that soybean yield is determined mostly by the number of pods than by other production components (Yashima et. al., 2005 & Borges et. al., 2014). Soybean has a high percentage of aborted flowers, ranging from 27 to 78% of the total amount of flowers (Peterson et al., 2005). Flower abortion and abscission can occur at several stages of soybean reproduction (Carlson et al., 1987). Flower and pod setting mechanisms are not fully understood (Passos et al., 2011). However, hormonal balance is believed to have significant influence on the flower and pod attachment rate.

Little is known about the physiological effect of growth regulators on the floral development of soybean plants. There is no conclusive information, and explanations on the subject still lack investigation. Aiming to reduce the abortion of reproductive organs, the present study was designed to evaluate the effects of benzyladenine in the abortion of reproductive structures and in soybean plant productivity.

Material and methods

Experimental design

The work was conducted in Ipameri, Goiás (Lat. 17º67'90"S, Long. 48º19'59"W, Alt. 805 m). According to Köppen classification, this region has Aw-type climate, characterized by humid tropical climate with rainy summers and dry winters. Basically, there are two well-defined seasons: the rainy season, from October to April, and the dry season, from May to September. The soil of the experimental area is classified as Oxissol. After soil analysis, fertilization and pH correction was accomplished according to technical harvest recommendations (Prochnow et al., 2010). Was used 120 Kg ha^{-1} of Potassium Chloride (KCl) to the haul at 10 days before sowing and fertilization at the time of sowing with application of 350 kg ha^{-}

[1] of the formulated: 04-30-10. The sowing of soybean Pioneer 98Y12 RR was performed on mid-november.

First, a stock solution of the growth regulator was prepared, by dissolving 2 g of benzyladenine in 8 ml of 1 N of NaOH solution. Then the volume was completed to 50 ml with distilled water. From the dilution of the solution obtained and work studies developed by Borges et al. (2014) and Pan et al. (2011) it was decided to use the following doses of benzyladenine in soybean plants: 0; 100; 200; 300 and 400 mg L^{-1} of benzyladenine applied during the V_6 stage, with 200 L ha^{-1} (120 ml per plot) spray volume applied in the early morning between 08:00 and 09:00 h in five replications. The experiment was conducted according to the randomized block design. The experimental area was 3 x 2 m and about 90 plants were studied in rows spaced by 0.5 m and with 10 plants per meter. Seeking maximum uniformity during the application, benzyladenine was sprayed onto the leaves of soybean plants, using a backpack sprayer attached to a metering valve.

The following variables were analyzed: number of inflorescences per plant, total amount of chlorophyll and carotenoid, leaf stomata density, total leaf nitrogen, specific leaf area, oil content in the seed, plant height, number of branches per plant, number of pods in the upper, middle and lower thirds of the plant, 100 seed weight, yield, number of grains per plant and grain diameter.

Variables

The number of inflorescences per plant, number of branches, length and width of leaves and stem diameter were determined during the reproductive stage corresponding to R_2, that is, when most racemes presented blossomed flowers. The number of pods in the plant upper, middle and lower thirds was measured during the $R_{5.1}$ stage.

Specific leaf area (SLA)

To obtain the specific leaf area, six 12-mm-diametral leaf discs were removed from fully expanded leaves, which were then dried at 70 °C for 72 h to determine the dry mass. The SLA was obtained through the equation proposed by Radford (2013).

Photosynthetic pigments and total nitrogen

In order to determine the photosynthetic pigments, defined-area leaf discs were extracted and placed in glass containers with dimethyl sulfoxide (DMSO). Later, extraction was done in water bath at 65 °C for eight hours. Aliquots were taken for spectrophotometric reading at 480, 649 and 665nm. The chlorophyll (Cl *a*), chlorophyll (Cl *b*) and carotenoid (Car) contents determined through the equation proposed by Wellburn (1994). Leaf samples were collected and the total N concentration was determined, as described by Cataldo et al*.* (1975). Analyses were carried out during the reproductive phase corresponding to R_2.

The number of pods, seeds per pod, 100 grain weight, number of grains per plant, grain diameter and productivity were measured during reproductive phase R_9. The analysis of the 100-grain weight and productivity were adjusted to 13% moisture.

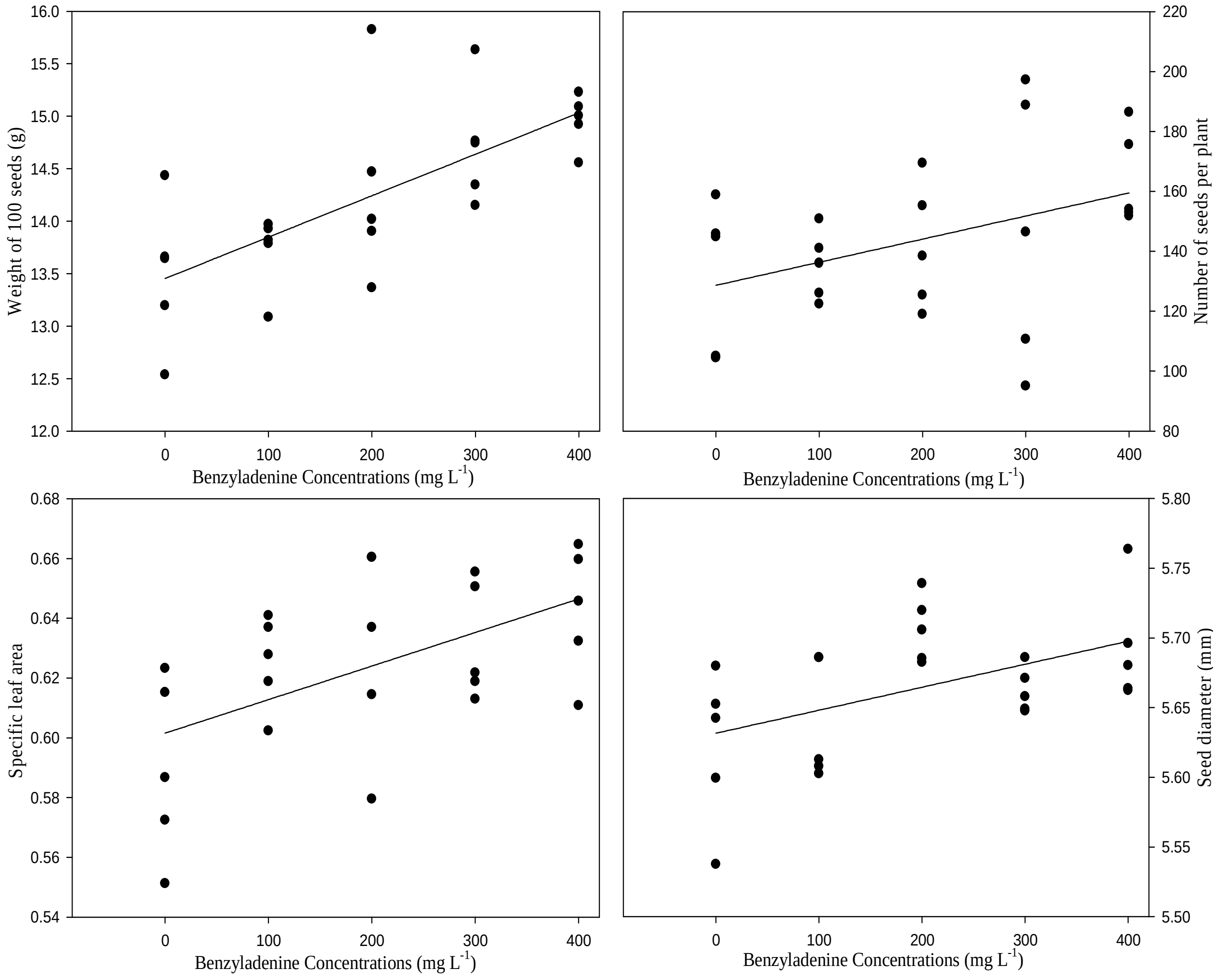
Statistical procedures

Variance analyses were conducted following the randomized block design in five treatments and five replications. Differences between treatments were assessed through regression analysis of the variables analyzed with the SISVAR (Ferreira, 2011).

Results

The 100-grain weight, number of grains per plant, specific leaf area and grain diameter showed a linear increase according to the benzyladenine doses (Figure 1). The 100-grain weight showed a difference of approximately 1.5 g, corresponding to a 10% increase, when the control is compared to a higher dose. When the same comparison is made for the number of grains, an increase of 31 grains per plant was found. The specific leaf area was 7.8% higher in leaves treated with higher doses than the controls. When the same comparison is made for grain diameter, there is an increase of 1.2%.

Figure 1 - Regression equations for 100-seed weight (Y = 13.455 + 0.0039X, R2 = 0.99 **), number of grains per plant (Y = 128.616 + 0.0772X, R2 = 0.97*), grain diameter (mm) (Y = 5.632 + 0.0002X, R2 = 0.99*), specific leaf area (Y = 0.602 + 0.0001X R^2 = 0.99*) of soybean plants treated with increasing doses of benzyladenine (0, 100, 200, 300 and 400 mg L^{-1}).



The abortion of pods in the lower, middle and upper thirds decreased with increasing doses of benzyladenine, while productivity increased with the benzyladenine dose (Figure 2). The reduction in abortion caused a 32% increase in the number of pods in the upper third of the plants treated with 400 mg L^{-1} benzyladenine in relation to the control plants, that is, an increase of 17.91 pods per plant. In the lower and middle thirds of the canopy the reduction in the abortion of pods on plants treated with 400 mg L^{-1} compared to control, provided an increase of around 26% (12.94 pods per plant) and 30% (5.84 pods per plant) respectively. The lowest number of aborted pods provided a 13% increase in productivity (463 kg ha^{-1}).

The leaf area and the number of branches increased linearly with increasing doses of benzyladenine (Figure 3). The leaf area and the number of plants treated with 400 mg L^{-1} benzyladenine showed an increase of 8% and 15%, respectively, in relation to the control. The leaf concentrations of chlorophylls (*a* + *b*), carotenoids and total nitrogen showed reduced variance due to the treatments applied. There was no statistical difference in any of the three variables analyzed. On average, leaf concentrations of chlorophylls (*a*+*b*), carotenoids and total nitrogen were about 4.5, 1.0 and 5.0 g kg^{-1} of dry matter, respectively.

Figure 2 - Regression equations for abortion of lower-third pods ($Y = 18.408 – 0.0137X$, $R^2 = 0.96$**), abortion of middle-third pods ($Y = 27.148 – 0,0261X$, $R^2 = 0.92$*), abortion of upper-third pods ($Y = 48.726 – 0.0379X$, $R^2 = 0.93$*), and productivity ($Y = 3033.978 + 1.141X$, $R^2 = 0.99$**) of soybean plants treated with increasing doses of benzyladenine (0, 100, 200, 300 and 400 mg L^{-1}).

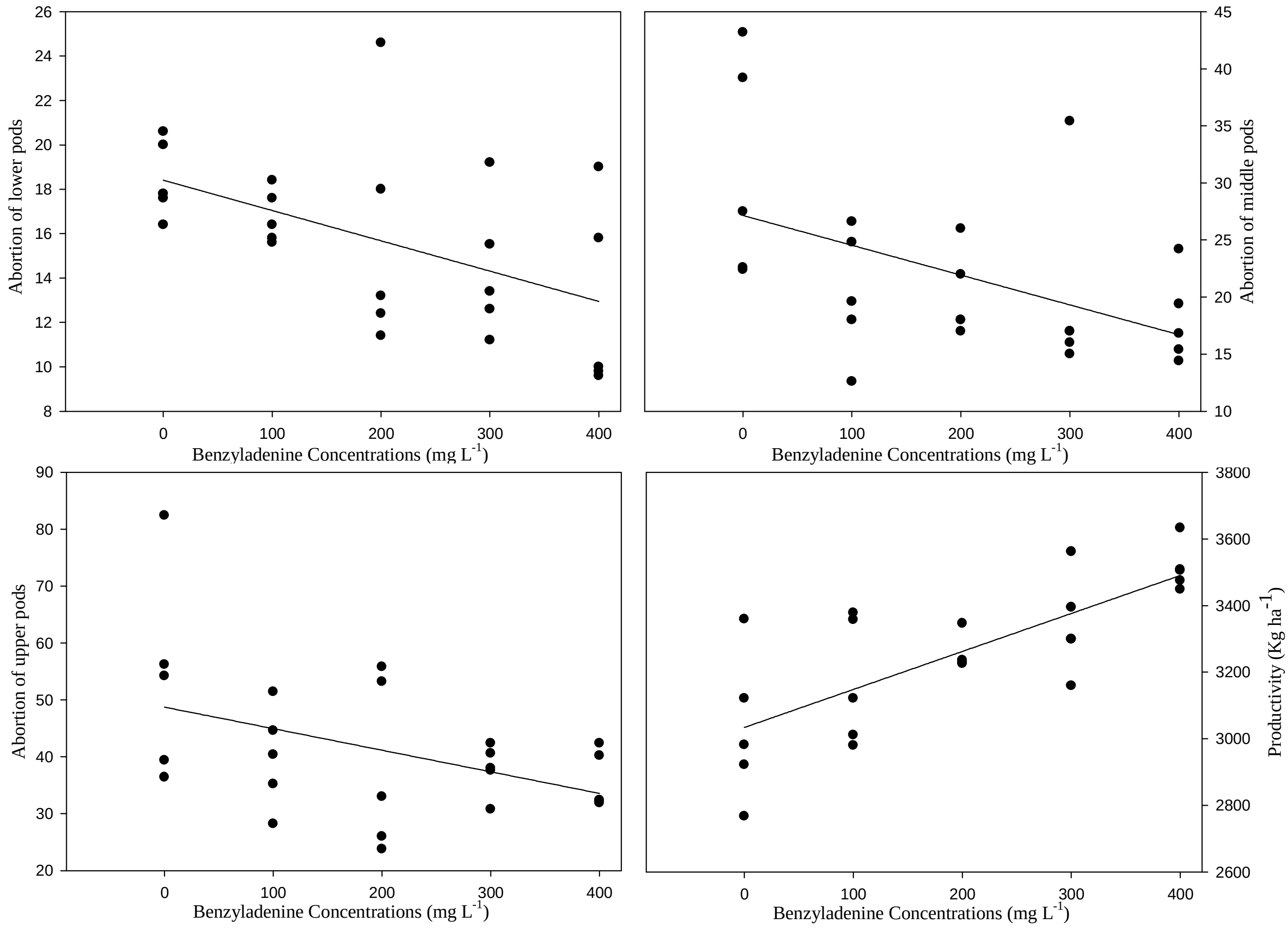
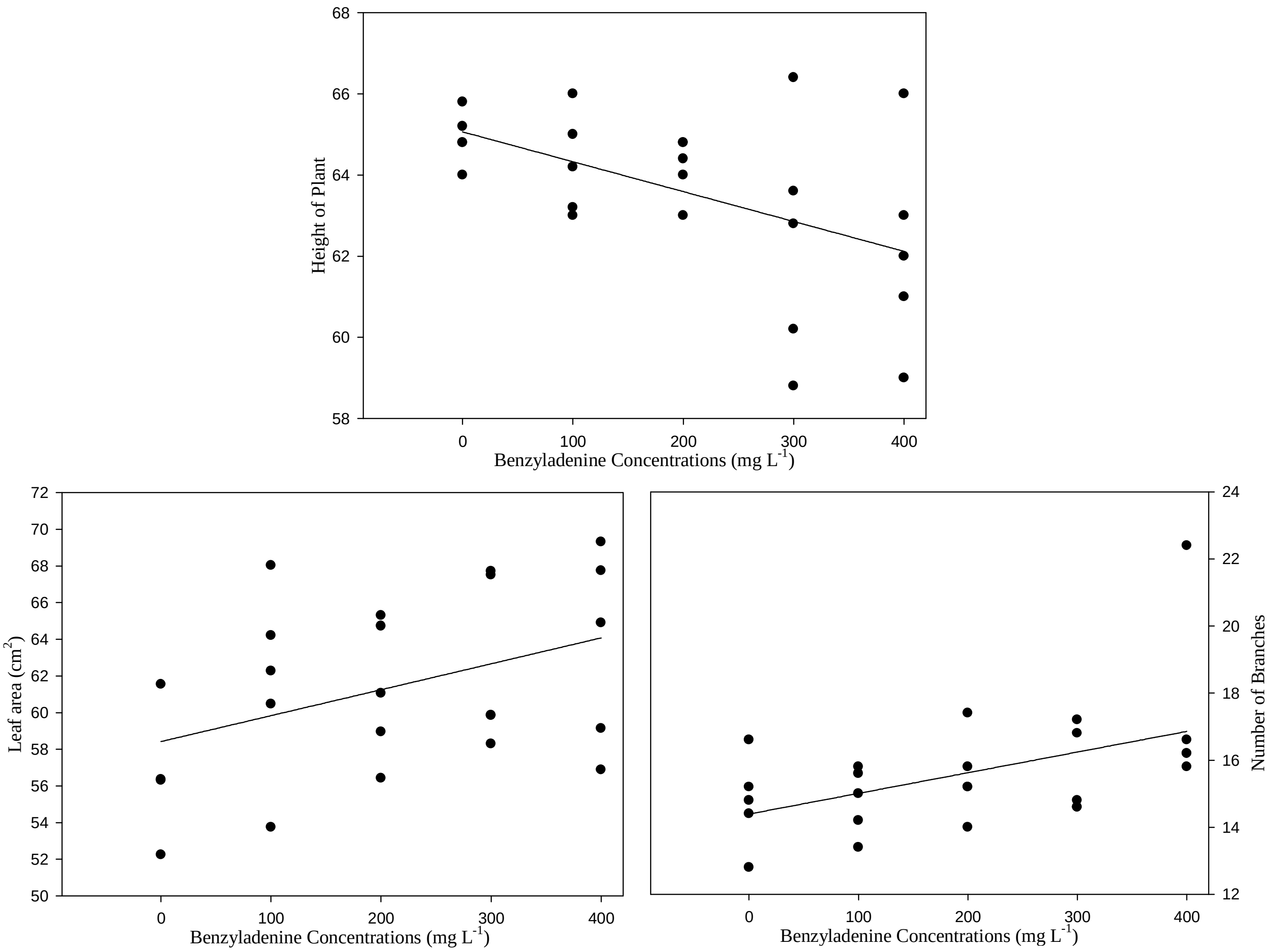


Figure 3 - Regression equations for plant height ($Y = 65.064 – 0.0074X$, $R^2 = 0.99^{**}$), leaf area ($Y = 58.4209 + 0.0141X$, $R^2 = 0.99^{**}$) and number of branches ($Y = 14.3920 + 0.0062X$, $R^2 = 0.99^{*}$) of soybean plants treated with increasing doses of benzyladenine (0, 100, 200, 300 and 400 mg L^{-1}).



Discussion

During vegetative growth of soybean plants, the stem and root tips are usually the main drains; seeds and fruits become the principal drains during reproductive development. The application of benzyladenine can alter the draining strength, photosynthesis (Borges et al., 2014), and promote greater allocation of assimilates to the plant reproductive organs. In an experiment conducted by Nagel et al., (2001), it was observed that plants treated with benzyladenine generally showed changes in the growth of the root system.

The application of benzyladenine provided an increase in the draining strength of the reproductive organs and possibly enhanced the translocation of assimilates to these organs, resulting in lower abortion of pods, higher 100-grain weight and grain diameter, higher number of pods per plant and increased productivity. The results corroborate those found by Borges et al. (2014), Carlson et al. (1987) and Passos et al. (2011) when evaluating the growth ans productivity of soybean plants treated with benzyladenine. Moreover, it should be noted that higher grain yield was only possible due to the increased capacity of sources to produce assimilates, which required anatomical and physiological changes.

Leaf expansion and larger specific leaf area may have contributed to the increased photosynthesis of plants treated with benzyladenine due to increased photosynthetic surface and optimized capturing of the light that reaches and crosses the canopy interior, increasing the amount of photosynthetically active radiation capable of reaching the lower strata of the soybean plant. Increased transmittance allowed for more photosynthesis to occur at the canopy level with direct effect on the production of photoassimilates. The increase in photosynthesis by the source possibly provided assimilates for the growth and development of new productive branches. In addition, there is the intrinsic ability of cytokinins to break apical dominance and dormancy of axillary buds.

The low availability of assimilates to reproductive structures is thought to be the cause of high abortion of soybean plant pods. The application of benzyladenine increases the draining strength of reproductive organs, enhances the unloading of assimilates, promotes anatomical and physiological changes that possibly increase the ability of sources to produce more assimilates, therefore increasing grain productivity. The low production of cytokinin in reproductive phase associated with competition for production factors among reproductive and vegetative organs limits the productivity of soybean plants (Nonokawa et al., 2012).

The results indicate that the use of benzyladenine may represent important management technology for soybean for influencing the setting of pods and increasing grain yield, as discussed below.

Conclusions

The application of benzyladenine reduced the abortion of pods increased vegetative growth and productivity of soybean plants, because the plant adapted morphologically and physiologically to optimize the capturing of solar radiation and increase the production of assimilates.

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