English Version

Soybean plants architeture and plant growth regulators application

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Abstract

Treatment with plant growth regulators was studied in soybean plants (*Glycine max* (L.) Merrill cv. BRS-184) to assess the leaf chlorophyll content, the branching number and the height of the pods. The experiment has been carried out in the greenhouse of the Department of Botany, Bioscience Institute, São Paulo State University – UNESP, Botucatu, SP, Brazil. The experimental design was completely randomized with three replications and eight treatments: control; GA_3 100 mg L^{-1}; BAP 100 mg L^{-1}; IBA 100 mg L^{-1}; Stimulate® (IBA + GA_3 + kinetin) 20 mL L^{-1}; mepiquat chloride 100 mg L^{-1}; mepiquat chloride 100 mg L^{-1} + BAP 100 mg L^{-1} + IBA 100 mg L^{-1} and ethephon 600 mg L^{-1}. The treatments were applied three times every 30 days during the plant cycle and six evaluations have been made every 13 days. The treatments with BAP, ethephon and mepiquat chloride + IBA + BAP maintained the high chlorophyll content until the end of the plant cycle. The height of the plants treated with ethephon was lower than the control and all treatments, excepting the treatment with GA_3. The number of plant branches was incremented by the ethephon treatment and the height of the first pod was the lowest in this treatment and the highest in the treatment with GA_3. The treatment of soybean plants with ethephon can be recommended on soybean, which promoted the formation of plants with the ideal architecture for mechanical harvesting.

Key-words: growth; chlorophyll; height of the pod; branching

Introduction

The soybean 2007/2008 crop was of 60.1 megagrams and it is estimated that the area with soybean plantation in Brazil in 2008/2009 is of 64 million hectares. Brazil was the second world major soybean exporter in 2006 (IBGE, 2010).

The soybean harvest constitutes an important stage on the productive process, mainly due to the risks that the filed is exposed to. During the harvest process it is natural the occurrence of losses, however it is necessary that these are reduced to a minimum. Physical and physiological factors may be the cause of grain loss on the mechanical harvest (EMBRAPA, 1999a), and, among them, plant height, number of branches and pod height may interfere on the process of loss by the mechanical harvest.

If the plantation is not well conducted losses may occur by plant lodging, caused by the uncontrolled plant growth, or the poor choice of cultivars may determine the appearance of small plants, with low insertion of the first pod and, thus, difficult the harvest.

In this case, the crop management becomes of major importance and one way to circumvent this problem is the use of plant treatment with different plant growth regulators, which are synthetic substances that, applied exogenously, have similar actions to the phytohormones (CASTRO et al., 2005).

With the use of plant growth regulators, plants become more compact and therefore more efficient physiologically. For this reason, one of the agronomical strategies to manipulate the plant architecture that may contribute to the increase on the yield is the use of plant growth regulators (LAMAS, 2001).

Phytohormones are involved in each aspect of the plant growth and development. These small molecules which function as highly specific chemical signs between cells are capable to regulate the plant development due to the fact that they produce amplified effects (RAVEN et al., 2001). These natural substances may be applied directly on the plants

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(leaves, fruits, seeds), providing alterations on the vital and structural processes, in order to increase the production, improve quality and facilitate harvest (VIEIRA e CASTRO, 2003).

The application of auxin and gibberelin provide longitudinal growth of the stem from different species, acting either on the elongation or on the cell division and, thus, providing plant growth (TAIZ e ZEIGER, 2009).

According to the same author, the exogenous applications of cytokinins provide the brake of the apical dominance and growth of the lateral buds; in direct application on the auxiliary buds of different species, they stimulate cell division and growth of these buds. Cytokinins also promote the development of chloroplasts, the leaf expansion and may interfere in the synthesis of chlorophyll.

Ethylene is an inhibitor of cell division, cell expansion and transport of auxin which presents expressive effects on the reduction of stem growth in length; however, it provides its radial expansion and horizontal orientation (COLL et al., 2001).

Thus, the objective of the work was to evaluate the influence of different plant growth regulators on the chlorophyll content, growth, number of branches, pod height in soybean plants (*Glycine max* (L.) Merrill) and the correlation of these data with the loss on mechanic harvest.

Material and methods

The experiment was conducted in a green house of the Department of Botanic, Bioscience Institute, State University of São Paulo – UNESP, Botucatu (SP). Plants were cultivated in 10 liter vases containing earth collected from the topsoil classified as Latossolo Vermelho Distrófico (EMBRAPA, 1999b)[1].

The earth was corrected with 1 g dm^{-3} of lime, in accordance with the recommendations of the chemical analysis of the soil. After the soil acidity correction, the earth was fertilized with 20 mg dm^{-3} of N; 200 mg dm^{-3} of P, 100 mg dm^{-3} of K and 10% of the total volume of the vase with dairy manure.

The soybean cultivar chosen to the sowing was BRS-184, which results from the breeding 'FT Guaíra' x 'IAC-13-C', indicated to the states of São Paulo and Paraná. It presents good growth and branches, good resistance to diseases and is indicated to soils from medium to high fertility. Seeds were treated with the fungicide Captan [(N- trichloromethylthio-4-cyclohexane-1,2-dicarboximide] 500 g kg^{-1} and Benomyl (methyl-1-(butylcarbamoyl)-2-benzimidazole-carbamate) 500 g kg^{-1} on the dosage of 3 g kg^{-1} and 0,4 g kg^{-1} of seeds respectively, and inoculated with peat sterilized with gamma rays.

The experiment design used was completely randomized with three replications and eight treatments. The following treatments with plant growth regulators were used: T1 – control (water); T2 - GA_3 100 mg L^{-1}; T3 - BAP (benzylaminopurine) 100 mg L^{-1}; T4 - IBA (indolebutyric acid) 100 mg L^{-1}; T5 - Stimulate® (IBA + GA_3 + kinetin) 20 mL L^{-1}; T6 - Mepiquat chloride (Cl mep.) 100 mg L^{-1}; T7 - Cl mep. 100 mg L^{-1} + BAP 100 mg L^{-1} + IBA 100 mg L^{-1} e T8 - ethephon 600 mg L^{-1}.

As plant growth regulator sources, it was used: to gibberelin the commercial product ProGibb®, containing GA_3 (gibberellic acid) at 10%; Stimulate®, commercial product containing the mixture of IBA at 0,05 g L^{-1}, GA_3 (gibberellic acid) at 0,05 g L^{-1} and kinetin ta 0,09 g L^{-1}; PIX®, commercial product containing mepiquat chloride at 5% and Ethrel®, commercial product containing ethephon (acid 2-chloroethyl-phosphonic) at 240 g L^{-1}.

The treatments were applied by foliar spray 43, 74 and 105 days after sowing. The evaluation of the plants was performed in 6 samplings, each 13 days, 60, 73, 86, 99,112 and 125 days after planting (DAP).

The characteristics evaluated were: chlorophyll content (spad), plant height (cm), number of branches per plant and height of the pod closest to the soil (1st pod height – cm). To measure the chlorophyll content it was used the chlorophyll meter Minolta SPAD-2.

The results were submitted to variance analysis (F test) and adjusted to the mathematic model of regression analysis to each treatment.

Results and discussion

The treatment of the soybean plants with

1 Corresponding to Rhodic Hapludox, according to Soil taxonomy

GA_3 provided higher plant growth during all the cycle (Figure 1 ant Table 1), which demands the monitoring of them to avoid lodging. Castro et al. (1990) verified increase on plant growth of the ‘Carioca’ bean treated with gibberelin at 50 mg L^{-1} 14 and 21 days after application. Leite (1998) also observed that soybean plants treated with GA_3, through the leaves, presented an increase in plant height. The other treatments, from 86 days of planting, presented plant height similar or inferior to the control, as it happened with plants treated with ethephon and mepiquat. The application of ethephon in bean (*Phaseolus vulgaris* L.) 7, 14 and 28 days after plant emergence reduced plant growth, and did not provide increase in the production (NGATIA et al., 2003). According to Campos et al. (2007), plant treatment with mepiquat chloride and ethephon, inhibited plant growth and increased the lifecycle of the plant.

The number of lateral branches of the plants increased significantly on the treatment with ethephon during all the plant cycle (Figure 2 and Table 2). When Tancredi et al. (2004) removed the apical meristem of soybean plants at 25 cm height, they obtained an increase in plant branching and in grain yield. In fact, the stress caused by pruning promoted

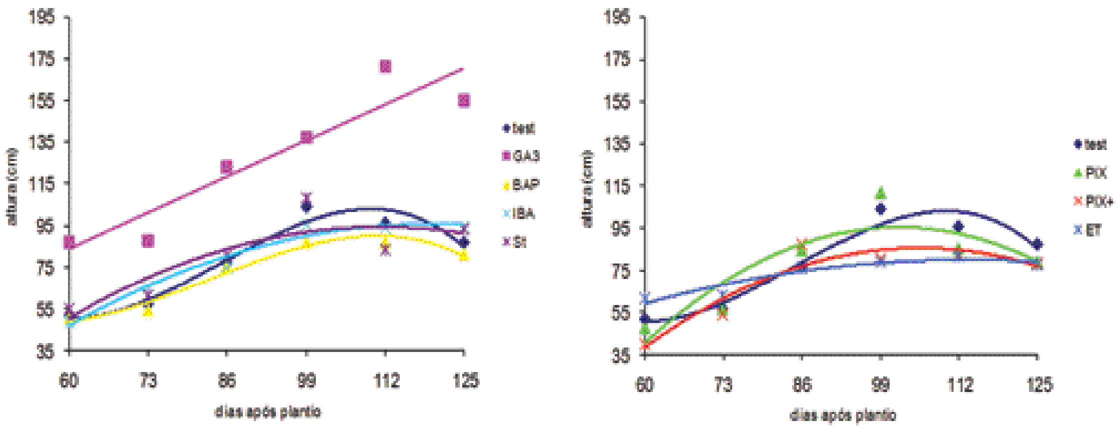

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Figure 1. Soybean (*Glycine max* (L.) Merrill cv. BRS-184) plant height in relation to different treatments with plant growth regulators: (A) Control, GA_3, BAP (benzylaminopurine), IBA (indolebutyric acid) e Stimulate® (GA_3+IBA+kynetine); (B) Control, PIX® (mepiquat chlorite), PIX®+ (mepiquat chlorite +BAP+ IBA) e ET (ethephon).

Tabela 1. Modelo da função ajustada e R^2 dos tratamentos referentes à altura de plantas de soja em função dos tratamentos com reguladores vegetais.

Tratamento	Modelo (Função ajustada)	R^2
Testemunha	$y= 469.440 - 17.023x + 0.219x^2 - 0.000859x^3$	0.816
GA_3	$y= 17.782 + 1.212x$	0.748
BAP	$y= 258.700 - 9.080x + 0.123x^2 - 0.000491x^3$	0.882
IBA	$y= - 108.799 + 3.505x - 0.0151x^2$	0.900
GA_3+IBA+cinetina	$y= - 111.532 + 3.700x - 0.0166x^2$	0.701
Cloreto de mepiquat	$y= - 230.215 + 6.389x - 0.0313x^2$	0.506
Cloreto de mepiquat+BAP+IBA	$y= - 150.493 + 4.363x - 0.0203x^2$	0.887
Ethephon	$y= - 15.743 + 1.694x - 0.00748x^2$	0.761

an increase on the ethylene synthesis and also caused a break on the apical dominance, providing higher cytokine content to the development of the lateral buds, which was responsible for the physiological responses. While Bhattacharjee and Divakar (1989) verified the effect of ethylene in *Jasminum* spp. on the dosage of 100, 500 and 1000 mg L^{-1}, they observed a decrease in the growth, increase in the number of brunches, increase on stem thickness and a late flowering period, although with a larger number of flowers.

The height of the first pod close to the soil followed plant growth. Those treated with GA_3 had the largest distance from the soil surface and also presented the superior first pod height during all the reproduction period, achieving 35 cm of the soil surface 86 days after planting (Figure 3 and Table 3). Leite (1998), working with gibberelin in soybean, verified that the application in leaves of 100 mg L^{-1} of GA_3, associated or not to the application of cytokines, resulted in higher plants. When applied between the stages V3/V4, it provided a significant increase in the first node height, and also higher increase of lateral buds.

Ethephon inhibited plant growth and, consequently, reduced the first pod height in comparison to the control and other treatments. This fact may be harmful to the harvest, providing

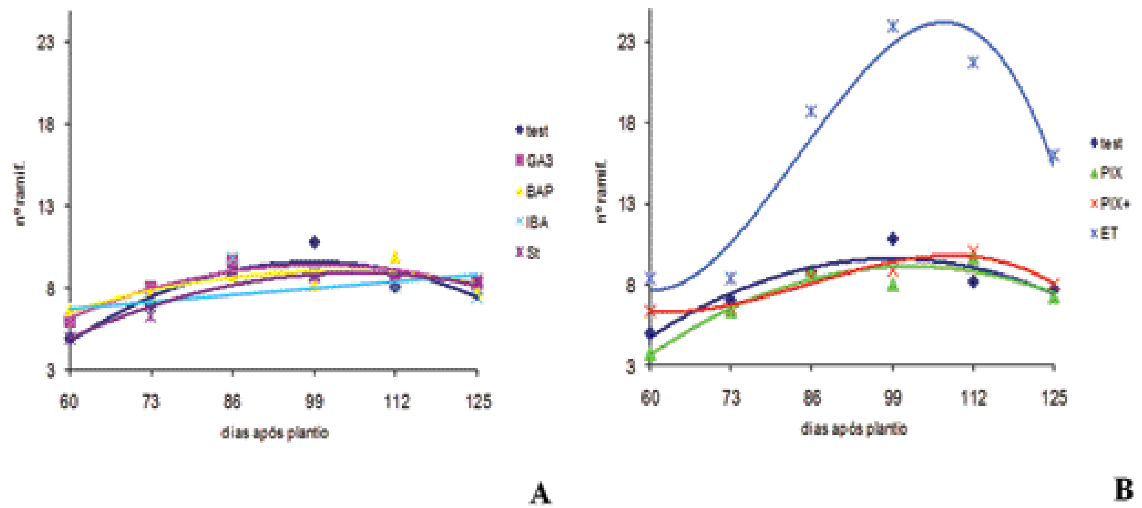

Figure 2. Number of leashes per soybean plant (*Glycine max* (L.) Merrill cv. BRS-184), in relation to treatment with different plant growth regulators: (A) Control, GA_3, BAP (benzylaminopurine), IBA (indolebutyric acid) e Stimulate® (GA_3+IBA+kynetine); (B) Control, PIX® (mepiquat chlorite), PIX®+ (mepiquat chlorite +BAP+ IBA) e ET (ethephon).

Tabela 2. Modelo da função ajustada e R^2 dos tratamentos referentes ao número de ramificações por plantas de soja em função dos tratamentos com reguladores vegetais.

Tratamento	Modelo (Função ajustada)	R^2
Testemunha	$y= - 21.898 - 0.638x + 0.00322x^2$	0.671
GA_3	$y= -7.176 + 0.319x - 0.00157x^2$	0.529
BAP	$y= - 7.506 + 0.331x - 0.00164x^2$	0.431
IBA	$y= 2.813 + 0.0579x$	0.308
GA_3+IBA+cinetina	$y= - 12.351 + 0.413x - 0.00195x^2$	0.624
Cloreto de mepiquat	$y= - 22.993 + 0.629x - 0.00308x^2$	0.679
Cloreto de mepiquat+BAP+IBA	$y= 45.325 - 1.539x + 0.0193x^2 - 0.0000752 x^3$	0.749
Ethephon	$y= 161.069 - 6.255x + 0.0809x^2 - 0.000322 x^3$	0.973

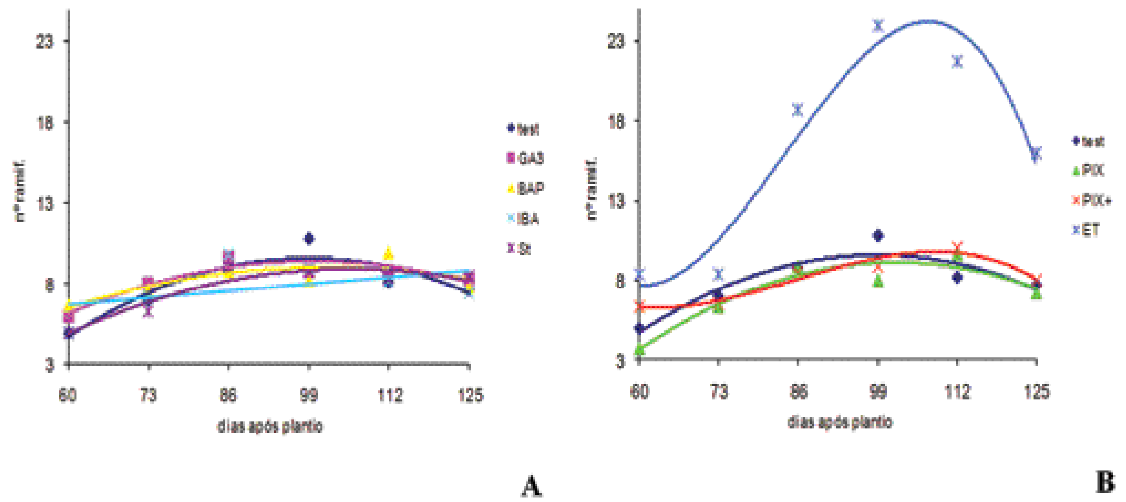

Figure 3. Height of the 1st pod (cm) of soybean plants (*Glycine max* (L.) Merrill), in relation to treatment with different plant growth regulators: (A) Control, GA_3, BAP (benzylaminopurine), IBA (indolebutyric acid) e Stimulate® (GA_3+IBA+kynetine); (B) Control, PIX® (mepiquat chlorite), PIX®+ (mepiquat chlorite +BAP+ IBA) e ET (ethephon).

loss in field where it is performed mechanically (Figure 3). It can also be observed that 86 days after planting plants treated with ethephon presented no pods, while it could be observed on other treatments their presence. This suggests that the treatment with ethephon delayed the phenological cycle of soybean.

The treatment with mepiquat chlorite, which is an inhibitor of the GA synthesis, therefore, a plant growth retardant, did not reduce the 1st pod height, presenting a similar behavior to the other treatments, with the exception of the treatment with ethephon. To Marcos Filho (1986), the variety chosen to the plantation on a certain location must present height of the first legume insertion of at least 10 to 12 cm. However, according to the author, to most of the conditions of the soybean crops, the most satisfactory height is approximately 15 cm, even though most modern harvesters may perform good harvest with plants presenting legume insertion of 10 cm. The environmental factors or crop practices that affect plant height may influence also on height of the first pod insertion (SEDIYAMA et al., 1972).

Plant height is a characteristic of major importance when determining the cultivar to be introduced to a region, and may vary considerably according to the sowing period, plant spacing between and within the rows, humidity supply, temperature, soil fertility and other general environmental conditions (CARTTER e HARTWIG, 1962). It is considered plant height between 60 and 120 cm

Tabela 3. Modelo da função ajustada e R^2 dos tratamentos referentes à altura da 1ª vagem em função dos tratamentos com reguladores vegetais.

Tratamento	Modelo (Função ajustada)	R^2
Testemunha	$y= 66,628 - 0,9256x + 0,0042\ x^2$	0,838
GA_3	$y= - 941,74 + 29,71x - 0,2962x^2 + 0,001x^3$	0,987
BAP	$y= 144,47 - 2,3816x - 0,011x^2$	0,968
IBA	$y= - 1035,8 + 29,806x - 0,2761x^2 + 0,0008x^3$	0,997
GA_3+IBA+cinetina	$y= - 65,879 + 1,6221x - 0,0078x^2$	0,985
Cloreto de mepiquat	$y= 848,27 - 23,81x + 0,2257x^2 - 0,0007x^3$	0,965
Cloreto de mepiquat+BAP+IBA	$y= - 517,43 + 14,608x - 0,1311x^2 + 0,0004x^3$	0,899
Ethephon	$y= - 1583,5 + 43,163x - 0,3858x^2 + 0,0011x^3$	0,966

as appropriated to harvest mechanization.

Ethephon, even reducing plant height and first pod insertion, achieved the height of approximately 75 cm and first pod insertion at 15 cm from the soil surface, and, moreover, provided higher branching, which can provide a larger yield. Thus, it is a treatment that may be use to avoid soybean plant lodging.

Regarding to the chlorophyll content on the leaves it may be observed that all the treatments presented the same behavior during the evaluated period (Figure 4). However, 125 days after planting it was verified that treatments with BAP and ethephon still presented high content of chlorophyll on leaves, i.e., they delayed the stage of senescence. According to Taiz and Zeiger (2009), cytokines promote the development of chloroplasts and inhibit the chlorophyll degradation and, thus, prolong the plant photosynthetic period which will contribute to the production of soybean seeds (GULLUOGLU et al., 2006). According to Nooden (1986), soybean plants treated with GA_3 or GA_{4+7} on the segments of the main stem and of the leaves with pods had the leaf longevity increased for more than 15 days and the yellowing of pods was delayed for 2 to 4 days, when they were applied combined with cytokines.

By contrast, the ethephon may have delayed the phenological cycle of the crops and the treatment with mepiquat chlorite + IBA + BAP also maintained the chlorophyll content high in the end of the crop cycle, which reinforces the fact that cytokines inhibit the degradation of chlorophyll on plants. The non-degradation of chlorophyll on the tissue maintain them photosynthetically active, thus, it provided larger quantity of organic matter to the grain filling, leading to the formation of heavier grains, and, consequently, increasing grain productivity.

Conclusion

From the results obtained and on the conditions of this experiment, it may be concluded that:

The application of ethephon at 600 mg L^{-1} provided an increase in lateral branches in soybean plants, inhibited the plant growth and delayed the chlorophyll degradation, but did not reduce the height of 1st pod insertion; therefore it can be recommended to prevent soybean plant (*Glycine max* (L.) Merril cv. BRS-184;) lodging;

The treatment with BAO and mepiquat chlorite + IBA + BAP maintains the chlorophyll content high to 125 days after planting and

The treatment with GA_3 provided higher increase in soybean plant height.

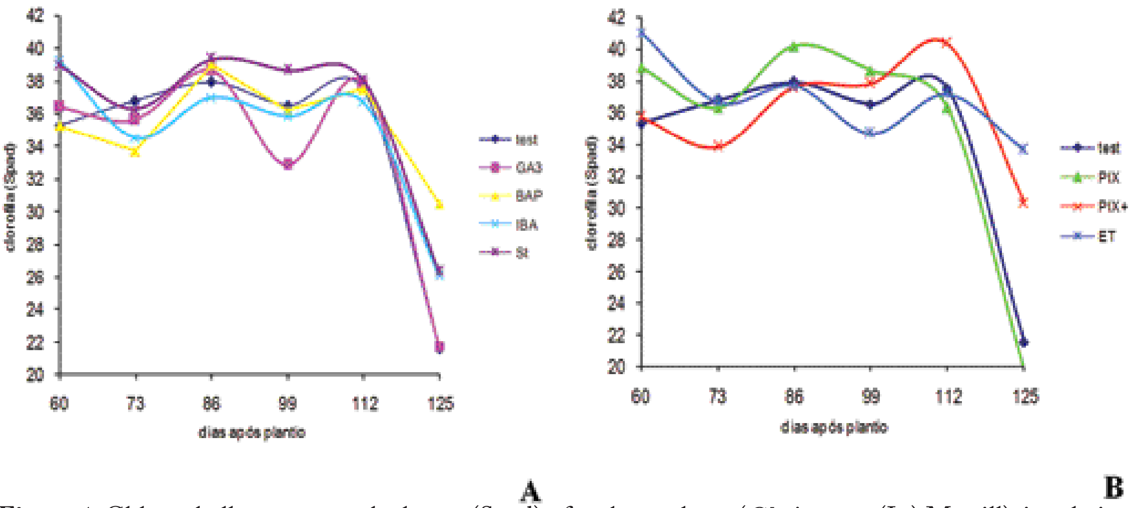

Figure 4. Chlorophyll content on the leaves (Spad) of soybean plants (*Glycine max* (L.) Merrill), in relation to treatment with different plant growth regulators: (A) Control, GA_3, BAP (benzylaminopurine), IBA (indolebutyric acid) e Stimulate® (GA_3+IBA+kynetine); (B) Control, PIX® (mepiquat chlorite), PIX®+ (mepiquat chlorite +BAP+ IBA) e ET (ethephon).

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