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GROWTH AND YIELD OF THE COMMON BEAN IN RESPONSE TO COMBINED APPLICATION OF NITROGEN AND PACLOBUTRAZOL[1]

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ABSTRACT - Nitrogen fertilization is a common practice used to increase the yield of winter bean crops. However, this practice leads to excessively tall and prostrate plants that have too many leaves, resulting in self-shading, and low yield and grain quality. The use of growth regulators could minimize the undesired effects of nitrogen fertilization. This study aims to determine the optimal concentration of paclobutrazol (PBZ) for inhibiting bean growth using the cultivars BRS Pontal and BRS Supremo. The plants were treated with PBZ at different concentrations, and also in combination with ammonium sulfate ten days after fertilization. The height and yield of plants were evaluated. It was observed that PBZ at 8 mg L^{-1} effectively inhibits the growth of bean plants, and increases the number of pods and grains. Higher concentrations of PBZ proved to be phytotoxic. Additionally, the application of PBZ ten days after fertilization with ammonium sulfate did not suppress the overgrowth of bean plants, and did not affect their yield.

Keywords: Gibberellin. *Phaseolus vulgaris* L. Plant regulator.

CRESCIMENTO E PRODUÇÃO DE FEIJOEIRO COMUM EM RESPOSTA A APLICAÇÃO COMBINADA DE NITROGÊNIO E PACLOBUTRAZOL

RESUMO - Em culturas de feijoeiro de inverno é comum o uso de doses elevadas de nitrogênio na busca de altas produtividades, resultando em plantas com altura excessiva, prostradas, com excesso de folhas, provocando autossombreamento e queda na produtividade e na qualidade dos grãos. A utilização de um regulador de crescimento poderia ser uma alternativa inibindo o crescimento excessivo das plantas contornando o problema. O presente trabalho teve por objetivo determinar a melhor concentração do regulador paclobutrazol (PBZ) para o feijoeiro, cultivares BRS Pontal e BRS Supremo, e avaliar os seus efeitos, quando combinado com a adubação nitrogenada, na altura das plantas, e nos componentes da produtividade, assim como o seu efeito na inibição do crescimento excessivo das plantas aplicado dez dias após a aplicação de sulfato de amônio. Observou-se que o PBZ é um regulador de crescimento efetivo na redução da altura de feijoeiros e aumento no número de vagens e grãos. A concentração de 8 mg L^{-1} é a que melhor resultado apresenta para estes efeitos, sendo fitotóxicas concentrações mais elevadas. A aplicação de PBZ posteriormente a adubação nitrogenada de cobertura não reverte o efeito desta quanto à indução do crescimento exagerado das plantas e não interfere na produtividade.

Palavras-chave: Giberelina. *Phaseolus vulgaris* L. Regulador de crescimento.

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INTRODUCTION

The cultivation of bean plants during the winter, or third-season irrigated, especially in the Cerrado region, has already accounted for more than 16% of the Brazilian production of the grain. Although the bean is a leguminous vegetable, able to fix atmospheric nitrogen (N) via a symbiotic association, naturally or through inoculation, it cannot fully meet the demand for N when farmers aim to increase productivity (COMISSÃO TÉCNICA SUL-BRASILEIRA DE FEIJÃO, 2009). Bean producers during this season apply excessive doses, above 80 kg ha^{-1} of nitrogen, resulting in overgrown plants, which grow flatter and demonstrate self-shading, creating a disease-prone environment, resulting in a fall in productivity and grain quality (FAGERIA et al., 2014; PORTES, 2012).

To decrease the duration of the vegetative stage of certain cultivars, or prevent overgrowth due to excess nitrogen, growers can make use of growth inhibitors. Paclobutrazol (PBZ) is an important regulator known to inhibit vegetative growth. It inhibits the synthesis of gibberelin by blocking the monooxygenase activity of cytochrome P-450, which in turn inhibits the oxidation of ent-kaurene to ent-kaurenoic acid in their biosynthetic pathway (HEDDEN; GRAEBE, 1985; RADEMARCHER, 2000).

PBZ is most effective when it is applied to the soil, owing to its better absorption by the roots (SHARMA; AWASTHI, 2005; IUCHI et al., 2008). Once absorbed, it travels through the xylem, reaching the meristematic regions, and then acts as an inhibitor, or negative modulator, of cell division. PBZ does not result in cytotoxicity when applied at low concentrations (TARI; MIHALIK, 1998; RIBEIRO et al., 2007).

The use of PBZ in bean plants fertilized with high doses of nitrogen could control the overgrowth of plants, helping to facilitate management, improve light penetration in the canopy, control the spread of disease, and improve product quality.

The genotypes BRS Pontal and BRS Supremo are widely used in Brazilian commercial bean crops. They are considered to have the genotypic potential for high productivity, as BRS Pontal features carioca -type beans and prostrated architecture, and the BRS Supremo is a bean plant with black grains and tall growth (FERNANDES et al., 2015; NASCENTE et al., 2012).

This study aimed to determine, in the first experiment, the best concentration of PBZ for beans, and then assess, in the second experiment, its effects when combined with nitrogen fertilization, in terms of plant height, pods per plant, total mass of 100 grains, and grain production for the cultivars BRS Pontal and BRS Supremo of *Phaseolus vulgaris* L.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse at the experimental area of the Department of Botany of the Universidade Federal de Goiás, in Goiânia, Goiás, located at 16° 36″ S and 49° 13″ W, at an altitude of approximately 800 m. Two experiments were conducted, both with completely randomized design, with four replications. The first experiment aimed to determine the optimal concentration of PBZ needed to reduce the size of the bean plants. The second experiment examined the effect of PBZ in excessive vegetative growth inhibition, when applied after nitrogen fertilization.

The soil used in the experiment was a dark red latosol, whose chemical characteristics, measured before the experiment, were as follows: pH ($CaCl_2$) 5.2; P available (Mehlich I) 2.3 mg kg^{-1}; K 50 mg kg^{-1}; Ca 5.7 cmolc kg^{-1}; Mg 0,5 cmolc kg^{-1}; cation exchange capacity (CEC) 9.4 cmolc kg^{-1} and organic matter (OM) 30 g kg^{-1}.

In the first experiment, we used the cultivar (C) BRS Pontal, with two plants per pot after thinning, treated with eight concentrations of PBZ: 0.5 mg L^{-1}, 0.7 mg L^{-1}, 1 mg L^{-1}, 2 mg L^{-1}, 4 mg L^{-1}, 6 mg L^{-1}, 8 mg L^{-1} and 10 mg L^{-1} applied 30 days after emergence (DAE), via soil, with one pot representing a repetition. The Cultar product (whose active ingredient is PBZ) containing 250 g L^{-1} of PBZ, was diluted in water to the desired concentration and applied in a single dose (1000 mL per 10-kg pot). To the obtained results were mathematically analyzed, using equations derived from correlation coefficients (r) and, the significance adjustment was tested by the F test, using the Fit Lab application.

Fertilization corrections were made based on 0.47g of fertilizer 4-30-15 + 0.5% of Zn per kg of soil sourced from a soil layer between zero and 0.20 m from an area near the site of the experiment.

In the second experiment, the scheme 2 × 2 × 2 consisted of two common bean cultivars, BRS Supremo and BRS Pontal, which were subjected to two levels of nitrogen applied in coverage (N1 = 0.2 g kg^{-1} and N2 = 0.3 g kg^{-1}) and two doses of PBZ, P1 = 0 mg L^{-1} (control) and P2 = 8 mg L^{-1}, totaling eight treatments, with a pot, containing two plants, representing one repetition. Fertilization correction was identical to that used in the previous experiment (1). The coverage fertilization was made on 20 DAE, using ammonium sulfate in soil taken from the soil layer between zero and 0.20 m in an area near the experiment. The PBZ was applied at 30 DAE via soil. The product was diluted in water to the desired concentration and applied as a single dose (1000 mL per 10 kg pot).

The heights of the plants were determined at harvest with a millimeter ruler, from base to apex of the main stem. After harvesting, pods were removed and counted per plant. The pods were threshed, the grains were separated, and number of seeds per pod was counted. The mass of 100 grains was determined after drying the seeds in an oven at 40ºC for 24 h. The total mass of grains was obtained by weighing all the grains harvested from the plants. Throughout the experiment, the maximum and minimum temperatures ranged between 19°C and 37°C, which were measured with a thermo hygrometer. Statistical analysis was performed by applying the F test, and the measures assessed by Tukey's test, at a level of 5% probability using the Assistat software.

RESULTS AND DISCUSSION

The results of the first experiment demonstrated that the ideal PBZ concentration for beans, resulting in a reduction in plant height and increased production of pods and grains, was 8 mg L^{-1} (Figure 1). Higher dosages resulted in phytotoxicity, with leaf necrosis and damage to the stem. Similar to our results, Yinet al. (2011) also observed an increase in grain production in beans by using PBZ in small concentrations, and Hegazie El-Shraiy (2007) observed a reduction in plant height, and increase in biomass. In the present work, the lowest plant height was observed in response to that concentration of PBZ that resulted in the highest increase in the number of pods and grain yield per plant (Figures 1A, 1B, and 1C).

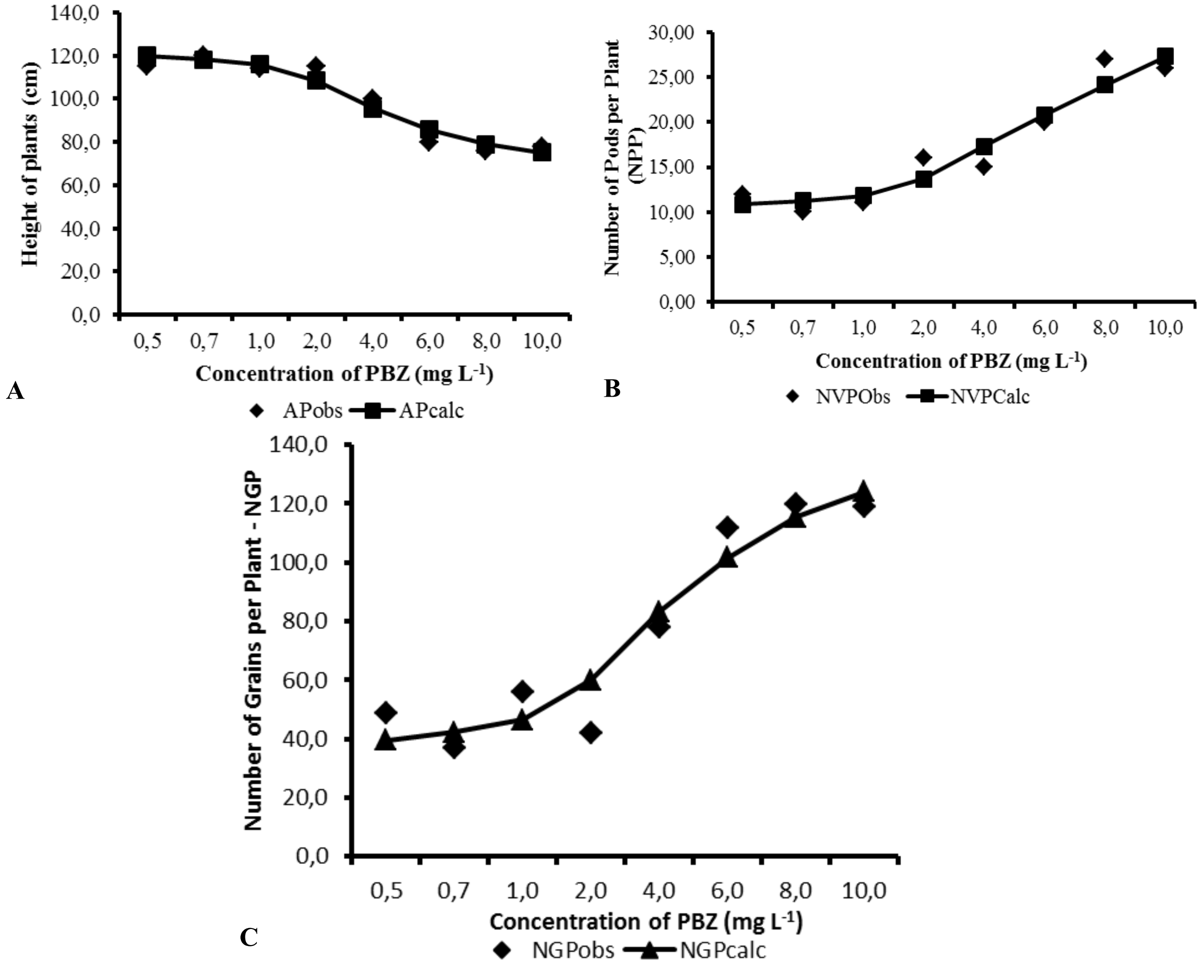

Figure 1. Height of the plant (A), Number of pods per plant (B) and Number of grains per plant (C) of bean plants treated with different dosages of paclobutrazol. Obs = observed values, Calc = calculated values. Significance level was set at 1%.

The effect of PBZ in reducing plant height and increasing grain production is also related to the ratio of photoassimilates, which are more often allocated to the reproductive organs than to aerial vegetative parts (HUA et al., 2014). The favorable responses to growth reduction and an increase in production in the bean plants have maximum effect up to a concentration of 8 mg L^{-1} PBZ (Figure 1); from 10 mg L^{-1} responses are inhibited, a fact also confirmed by Yin et al. (2011). It is expected that an increase in grain yield up to the inhibitory concentration of PBZ is probably due to the action of gibberellic acid concurrently stimulating the increase in stem biomass and inhibiting the formation of reproductive organs (POTTER et al., 1993).

Both, nitrogenous fertilizer and PBZ have been used together in some practices for the purpose of increasing grain yield and reducing plant growth (GEORGE; NISSEN, 1992; GITTI et al., 2012; NOURIYANI et al., 2012).

In the second experiment, the PBZ treatment, 10 d after application, did not control the exaggerated growth of the plants (Tables 1 and 2). The bean plants produced large amounts of biomass, and those that normally grew shrubby were prostrate, showing that the inhibitor, in the presence of nitrogen, was not effective. This is in contrast to what was observed when using only the PBZ without the application of high dosages of N (Figure 1). The two dosages of nitrogen applied (N) did not affect the characteristics of the cultivars (C) and the two dosages of PBZ regulator used (R), as well as the combinations C × N, C × R, N × R, and C × N × R, indicated that the regulator was not effective in inhibiting the excessive growth of bean plants subjected to high levels of nitrogen. The treatments only showed a difference in relation to plant height (length of the main stem) of the cultivar. This reflects a genetic trait, and for the cultivar BRS Pontal, the average height of the main stem was 133 cm, and the cultivar BRS Supreme measured 100 cm (Table 1).

Table 1. Values of F and CV% for the treatments, consisting of two bean cultivars (BRS Supremo and BRS Pontal - C), subjected to two nitrogen dosages (N) and two doses of the paclobutrazol regulator (P).

Treatment	Plant Height	N. Pods/Pl	N. Gr/Pods	Mass of 100 grains	Mass of grains
Cultivars-C	21,32**	10,60**	0,67ns	1,89ns	0,50ns
Nitrogen- N	0,38ns	10,60**	0,04ns	6,15*	10,53**
Regulator- P	1,66ns	2,40ns	0,00ns	3,37ns	3,23ns
C × N	0,57ns	0,80 ns	0,26ns	0,23ns	0,80ns
C × P	0,04ns	0,00ns	1,18ns	0,66ns	1,42ns
N × P	2,72ns	0,27ns	1,94ns	0,59ns	0,53ns
C × N × P	0,34ns	0,64ns	0,16ns	0,66ns	0,89ns
CV%	17,71	21,14	20,53	20,27	35,44

ns, * and **, not significant, significant to 5% and 1% of probability, respectively. N. Pods/ Pl = Number of pods per plant, N. Gr/Pods = Number of grains per pods.

Table 2. Comparison of means by Tukey's test at 5%, between different treatments, consisting of two bean cultivars (BRS Supreme - C1 and BRS Pontal - C2), submitted to two nitrogen dosages (N1 = 2 g/ pot and N2 = 3 g/pot) and two doses of paclobutrazol regulator (P0 = 0 mg L^{-1} and P2 = 8 mgL^{-1}).

Treatment	Plant Height (m)	N. Pods/P_l	Nr Gr/Pods	Mass of 100 grains	Mass of grains
C1	1,00b	7,78b	4,65a	13,06a	9,59a
C2	1,33a	9,94a	4,38a	11,83a	10,46a
N1	1,19a	7,78b	4,48a	11,34a	7,98b
N2	1,14a	9,94a	4,55a	13,55a	12,06a
P0	1,12a	9,37a	4,51a	13,26a	11,15a
P2	1,21a	8,34a	4,53a	11,63a	8,89a

Means followed by the same letter in the columns do not differ by Tukey's test at 5% of probability. N. Pods/P_l = number of pods per plant, N. Gr/Pods = Number of grains per pods.

It was observed that the BRS Pontal (C2) had a higher number of pods per plant, which was not reflected in grain production (Table 2). The application of ammonium sulfate resulted in a higher number of pods per plant, and grain production, even without the interference of the growth regulator (Table 2), as observed in other studies that link the grain production to the use of nitrogen (CARVALHO et al., 2001; FAGERIA et al., 2010; FAGERIA et al., 2014).

Although it has not been verified in this work, the influence of PBZ on grain production in the second experiment (Tables 1 and 2) is consistent with other studies. These have shown that the use of this regulator with a nitrogen fertilizer can increase fruit development and production higher than the use of nitrogen alone (GEORGE; NISSEN, 1992). PBZ seems to increase the absorption and transport of nitrogen by the plant (NOURIYANI et al., 2012). Camposet et al. (2008) found, however, that the regulators influence the response of many plant organs, but this response depends on the species, organ, developmental stage, concentration, and interaction between the other regulators and various environmental factors. The combination of these variables can even lead to a reduction in the grain production of specific bean cultivars, such as the IPR Juriti (GITTI et al., 2012). Pricinottoe Zucareli (2014) observed that the effects of PBZ application to control height and grain production in soybean depend on the development stage of the culture.

Nitrogen can stimulate the synthesis of auxin and cytokinin hormones, whose molecules contain this element. These hormones act as triggers of cell division and expansion processes, stimulating the formation of buds, lateral branches, and roots. This stimulates the growth and development of the plant (SAKAKIBARA et al., 2006; KIBA et al., 2011; LIU et al., 2011), though it can neutralize the effects of PBZ.

When comparing the effects of PBZ in experiments 1 and 2, experiment 1 showed that this regulator was effective in reducing plant growth and on factors affecting grain production, however these effects do not appear to be cumulative with the addition of nitrogen fertilizers. In experiment 2, the addition of nitrogen was found to determine the height of the plants and production components, irreversibly determining these characteristics even with the addition of PBZ.

CONCLUSIONS

Paclobutrazol is an effective growth regulator, reducing the height of bean plants and increasing the number of pods and grains of the cultivar BRS Pontal A concentration of 8 mg L^{-1} was optimal to achieve these characteristics.

The application of paclobutrazol at a concentration of 8 mg L^{-1} ten days after the nitrogen application, in the form of ammonium sulfate to the bean cultivars BRS Supremo and BRS Pontal, does not reverse the effect of the nutrient in terms of excessive growth and productivity.

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