



## Management of trinexapac-ethyl application in soybean

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**ABSTRACT:** This work aimed to evaluate the effects of using management of growth regulator trinexapac-ethyl (Moddus<sup>®</sup>) over plant height, lodging, productivity and grain yield of soybean plants (*Glycine max* (L.) Merrill. cv. BS 2606 IPRO). For that, an experiment was installed in field conditions, by using a randomized block design, with four replications; experimental unit was constituted of five lines of four meters in length, spaced at 0.45 m. Treatments were constituted by the application of growth regulator, as follows: without application; total dose between V3 and V4; total dose between V5 and V6; ½ dose between V3 and V4 + ½ dose between V5 and V6; total dose between V3 and V4 + total dose between V5 and V6, totaling five treatments. Productive components, mass of 100 grains and grain yield were evaluated. Results were not significant for studied variables regardless of management, differing only from the control.

**Keywords:** oilseed; lodging; plant regulator; application management; grain yield.

## Manejo da aplicação de trinexapac-ethyl na soja

**RESUMO:** Esse trabalho teve por objetivo avaliar os efeitos da utilização de manejos do regulador de crescimento (trinexapac-ethyl (Moddus<sup>®</sup>)) sobre altura, acamamento, produtividade e rendimento de plantas de soja (*Glycine max* (L.) Merrill. cv. BS 2606 IPRO). Com isso, instalou-se um experimento em condições de campo, com o delineamento experimental de blocos casualizados, com quatro repetições; a unidade experimental constituiu-se de cinco linhas de quatro metros de comprimento, espaçadas em 0,45 m entre elas. Os tratamentos foram constituídos pela aplicação do regulador de crescimento, sendo: sem aplicação; dose total entre V3 e V4; dose total entre V5 e V6; ½ dose entre V3 e V4 + ½ dose entre V5 e V6; dose total entre V3 e V4 + dose total entre V5 e V6, perfazendo cinco tratamentos. Foram avaliados os componentes produtivos, massa de 100 grãos e produtividade. Os resultados não foram estatisticamente significativos para as variáveis avaliadas independente dos manejos, diferindo apenas da testemunha.

**Palavras-chave:** oleaginosa; acamamento; regulador vegetal; manejo de aplicação; produtividade.

### 1. INTRODUCTION

Soy is the main grain crop in the country, and in the 2020/21 harvest approximately 38.47 million hectares were cultivated, with an estimated production of 135.5 million tons, which makes Brazil not only the largest producer, but also the world's largest exporter (CONAB, 2021).

New technologies are constantly being sought to increase the productivity of soybean crops, which avoid losses in grain yield and allow its adaptation to different climate change scenarios. In this sense, the causes of yield losses are diverse and occur both before, during and after harvest (AINSWORTH et al., 2008; VARSHNEY et al., 2011; PRATAP et al., 2012).

Lodging is positively correlated with plant height and can seriously damage production, causing yield losses in soybean cultivars, around 10% (SHERRIE et al., 2011). Under conditions that provide high vegetative development of soybean, plants become highly susceptible to lodging. With it, there is the shading of the leaves that previously received full radiation, causing disorganization of the canopy (MUNDSTOK; THOMAS, 2005). Shaded leaves, with less radiation interception, have a higher respiration/photosynthesis ratio than those with good sun

exposure, and can become photoassimilated drains, which can reduce the productive capacity of plants. Lodging also influences the morphological structure essential for the efficient use of carbohydrates and their translocation to the grain, and the earlier it occurs, the greater the reduction in grain yield and quality (ZANATTA; OERLECKE, 1991; ROCHA, 1996; LAWN; JAMES, 2011).

The reduction in grain quality occurs from deterioration, which is facilitated by increasing proximity to the soil (LOBATO, 2006). Two strategies are presented to solve the lodging problem in soybean: the use of cultivars with resistance to lodging (Lawn; James, 2011) and the use of plant regulators (BUZZELLO et al., 2013). As cultivars that present resistance to lodging do not always have high productive potential under certain environmental conditions, the use of growth regulators cannot be ruled out.

Plant growth regulators or phyto regulators are all chemical compounds that decrease cell division and elongation in meristematic tissues and physiologically regulate plant height (CATHEY, 1964). Synthetic compounds can be used to reduce unwanted longitudinal growth of plant shoots without decreasing grain yield (RADEMACHER, 2000). Phyto regulators are compounds

used in low concentrations, whose response can be either stimulatory or inhibitory on plant development processes (VIEIRA; CASTRO, 2004).

According to Campos et al. (2008), plant regulators influence the response of many plant organs, but this response depends on the species, plant part, development stage, concentration, interaction between other regulators and various environmental factors.

Plant growth regulators such as gibberellins biosynthesis inhibitors provide a reduction in plant size and this implies the targeting of metabolites to their reproductive structures (NÓBREGA et al., 1999). According to Fernandez et al. (1991), the application of the plant growth regulator (mepiquat chloride) affects the plant promoting the balance between the vegetative and reproductive parts, which can also be observed in the present study with the trinexapac-ethyl regulator.

The action of trinexapac occurs in the synthesis of gibberellins, which acts by deregulating the levels of active gibberellic acid (GA1), strongly increasing the levels of its biosynthetic precursor (GA20), which is found in conjugated form and is not active (NAKAYAMA et al., 1990). Through this, it cannot synthesize active gibberellins, so plants begin to synthesize and accumulate less efficient gibberellins, causing reductions in cell elongation (RADEMACHER, 2000; Taiz and Zeiger, 2006). The main gibberellin associated with stem elongation and activity in reproductive buds of several species is GA1, mainly from monocots (PERES; KERBAUY, 2004). The likely cause of plant growth inhibition is a drop in the level of active gibberellic acid (GA1) (WEILER; ADAMS, 1991; RADEMACHER, 2000). This inhibition is not as strong in dicots such as soybeans, thus justifying the selectivity of trinexapac for plants in this group.

Rademacher (2000) and Rodrigues et al. (2003), state that, generally, growth reducers have an antagonistic action to gibberellins and act by modifying their metabolism. The use of growth regulators obtains an interesting result, in which there is a reduction in plant height, in the sense of increasing the tolerance of plants to lodging, however, it does not reduce grain yield (SOUZA et al., 2013). Campos et al. (2010) also mention that, with the use of plant regulators, plants become more compact and thus more efficient from a physiological point of view. In the case of plant growth reducers, these are used to make the plant architecture more adapted and efficient in the use of environmental resources and inputs to achieve maximum agronomic yield (SOUZA et al., 2013).

In the case of soy, when working with plant regulators, its ability to provide development or avoid production limitations is plausible, however, significant increases in productivity may not occur, as other factors (humidity, temperature and radiation) can be severely limiting (CASTRO, 1980). The effect generated by the growth reducer depends on several factors, including: the dose used, the application and sowing time, the environmental conditions, the nutritional and phytosanitary status of the plant (RODRIGUES et al., 2003).

In this context, this work aimed to evaluate the effects of the use of growth regulator management (trinexapac-ethyl) on height, lodging and yield of soybean plants.

## 2. MATERIAL AND METHODS

The experiment was carried out at Fazenda Santa Terezinha, in the municipality of Tuneiras do Oeste, Paraná State, at the geographic coordinates 23° 50' 60" S and 52° 52' 10" W, at an altitude of 483 m. The region has a predominantly Cfa or subtropical climate, with hot summer, according to the Köppen classification (IAPAR, 2014). Table 1 shows the climate data during the entire experimental period, which began on October 22, 2019 and ended on March 6, 2020, obtaining a maximum temperature of 39°C and a minimum of 14°C, relative humidity of 79 % and total precipitation of 801.5 mm in a total of 36 days with rain.

Table 1. Climatic data during the entire experimental period (10/22/2019 to 03/06/2020), Tuneiras d'Oeste (PR) - 2019/20.

Tabela 1. Dados climáticos durante o período experimental (10/22/2019 até 03/06/2020), Tuneiras d'Oeste (PR) - 2019/20.

Lowest minimum temperature	14 °C
Highest maximum temperature	39 °C
Total precipitation	801.5 mm
Rainfall average	22.26 mm
Average precipitation per day/period	6.03 mm
Medium humidity	79%
Number of days with rain	36 days

Source: Coamo Cooperative Weather Station, headquartered in Moreira Sales-PR

The soil in the area is classified as Dystrophic Red Latosol (EMBRAPA, 2018) with a sandy texture. Before the installation of the experiment, chemical and granulometric analysis of the soil was carried out at a depth of 0.0-0.20 m, shown in Table 2. The experiment was installed in soil with 13% clay, 7% silt, 80% of sand, pH (CaCl<sub>2</sub>) 4.58 and organic matter of 8.69 g dm<sup>-3</sup>. This area had previously been cultivated with *Brachiaria ruziziensis*.

Table 2. Chemical attributes of the soil at the site before the implementation of the experiment, in the 0-20 cm layer.

Tabela 2. Características químicas do solo antes da implantação do experimento, coletada na camada de 0-20 cm de profundidade.

pH	P	M.O.	Ca	K	Mg	Al	CTC	V
CaCl <sub>2</sub>	mg	g dm <sup>-3</sup>	-----cmol.dm <sup>-3</sup> -----					%
	dm <sup>3</sup>	<sup>3</sup>						
4,58	13,67	8,69	1,70	0,23	0,72	0,2	6,02	44,1

P and K extracted with resin; Organic matter extracted by the Walkley-Black method; Ca, Mg and Al extracted with KCl 1 cmol L<sup>-1</sup>.

The experiment was carried out under field conditions, with the experimental design of randomized blocks, with four replications; the experimental unit consisted of five lines of four meters in length, spaced 0.45 m between them, considering as useful area the three central lines, totaling 4.05 m<sup>2</sup> of useful area, disregarding 0.5 m of both the ends.

The base fertilization was carried out using 300 kg ha<sup>-1</sup> of 04-30-10, based on the soil analysis and recommendation of Pauletti and Motta (2017). The soybean cultivar used in the experiment was BS 2606 IPRO, with characteristics such as medium size, indeterminate growth, root aggressiveness, tolerance in periods of water stress and to the root rot complex. Maturation group 6.0 and planting time and plant population recommendations are from October 1st to November 20th and 240 thousand plants ha<sup>-1</sup>, respectively.

The treatments were constituted with the application of the trinexapac-ethyl growth regulator (Moddus®), based on recommended doses for wheat and barley, considering 0.5 L ha<sup>-1</sup> of the commercial product, as follows: without application; total dose between V3 and V4; total dose between V5 and V6; ½ dose between V3 and V4 + ½ dose between V5 and V6; total dose between V3 and V4 + total dose between V5 and V6, making up five treatments.

During the experiment, the necessary cultural treatments were carried out to keep the area free of weeds, pests and diseases, throughout the development of the culture. Sowing was carried out on October 22, 2019 and harvesting on March 6, 2020, manually, in the useful area of each experimental plot after desiccation.

The variables evaluated were: yield components (number of pods per plant, number of grains per plant, number of grains per pod), weight of 100 grains, plant height and yield.

To determine the productive components, ten plants were collected at harvest. Afterwards, the pods were counted and threshed and the grains counted, determining the number of grains per plant, grains per pod and pods per plant.

For productivity in kg ha<sup>-1</sup>, plants were harvested from the useful area of each experimental plot, with threshing of the pods and weighing. The grains were separated to determine the mass of one hundred grains, by weighing two subsamples for each repetition used. Both assessments were standardized at 13% moisture (BRASIL, 2009).

Data were subjected to analysis of variance at a 5% probability level. The means were compared using the Tukey test at the same level of significance, using the Sisvar program (FERREIRA, 2011).

### 3. RESULTS

The application of the growth regulator increased the number of pods/plant and number of grains/plant, compared to plants without application (Table 3). On the other hand, application times and doses did not differ from each other.

The application of the growth regulator also did not affect the final plant population and mass of 100 grains, compared to plants without application (Table 4). However, it reduced plant height and increased productivity.

### 4. DISCUSSION

After applications of growth regulators, which inhibit the synthesis of gibberellin, plants may show an increase in the number of pods (HERTWIG, 1992). Zagonel et al. (2002) point out that plants with smaller height and more compact present better direction of the photoassimilates, increasing the number of reproductive structures per meter.

Crotalaria is influenced by growth regulators, both in its vegetative and reproductive development. In an experiment carried out by Freis et al. (2011) the increase in the doses of trinexapac-ethyl and paclobutrazol provided a greater number of pods and seeds per plant, compared to mepiquat chloride. Thus, as noted in the experiment by Novakoski et al. (2020), the application of post-emergence herbicides, such as lactofen (36 g ai ha<sup>-1</sup>) or chloransulam (33.6 g ai ha<sup>-1</sup>) on soybean (V3-V4), can also regulate plant height and not have a negative effect on the productive components of soybean. Linzmeyer Junior et al. (2008) observed that there was no

effect of trinexapac-ethyl doses on the number of pods per plant in soybean. However, under similar study conditions, Nascimento et al. (2009) tested the application of five doses of trinexapac-ethyl growth regulator in upland rice, and obtained a positive response from the application of trinexapac growth regulator on grain yield, at a dose of 150 g ha<sup>-1</sup> of ai, applied in the floral differentiation of the Primavera rice cultivar.

Table 3. Number of pods per plant, number of grains per plant and number of grains per soybean pod, as a function of the application of plant regulator. Tuneiras d'Oeste (PR) – 2019/20.

Table 3. Número de vagens por planta, grão por planta e grãos por vagem de soja, em função da aplicação de regulador vegetal. Tuneiras d'Oeste (PR) – 2019/20.

Treatment	Pod plant <sup>-1</sup>	Grain plant <sup>-1</sup>	Grain pod <sup>-1</sup>
No application	43.8 b	99 b	2.26
V3–V4 (E1)	54.9 a	125 a	2.27
V5–V6 (E2)	55.3 a	126 a	2.27
½(E1)+½(E)	56.7 a	130 a	2.29
E1 + E2	57.8 a	131 a	2.26
CV (%)	7.8	8.9	3.5
Test F	*	*	n.s.

E = season

n.s and \* = not significant and significant at 5% probability of error.

Means followed by the same letter in the column do not differ by Tukey test at 5% probability of error.

CV = coefficient of variation

Table 4. Plant height (cm), final plant population, weight of 100 grains (g) and yield (kg ha<sup>-1</sup>) soybean, as a function of plant growth regulator application. Tuneiras d'Oeste (PR) - 2019/20.

Table 4. Altura de plantas (cm), população final de plantas, massa de 100 grãos (g) e produtividade (kg ha<sup>-1</sup>) de soja, em função da aplicação de regulador vegetal. Tuneiras d'Oeste (PR) – 2019/20.

Treatment	Plant height (cm)	Final population of plants	100 grain mass (grams)	Productivity (kg ha <sup>-1</sup> )
No application	1,42 a	219.444	16,5	3.119 b
V3–V4 (E1)	1,24 b	241.667	16,0	3.793 a
V5–V6 (E2)	1,22 b	219.444	16,2	3.783 a
½(E1)+½(E)	1,26 b	258.333	16,1	3.859 a
E1 + E2	1,25 b	225.000	16,7	4.088 a
CV (%)	3,5	12,3	4,8	13,8
Test F	*	*	n.s.	*

E = season

n.s and \* = not significant and significant at 5% probability of error.

Means followed by the same letter in the column do not differ by Tukey test at 5% probability of error.

CV = coefficient of variation

The application of the growth regulator also did not affect the number of grains per pod (Table 3), as this characteristic is related to the genetic aspects of the highly heritable plant, not being much influenced by the environment or by exogenous factors (FREIRE et al., 2007). The number of grains per pod is not a character influenced by phytotechnical management practices, it is determined by the genotype itself (KAPPES et al., 2011). Maize seed mass is the productive component least affected by variations in management practices (SANGOI et al. 2002)

Chavarria et al. (2015), evaluating wheat yield components in the field, did not observe significant differences when trinexapac was applied in relation to the number of grains per ear. In an experiment in which growth

regulators were applied to soybean, Souza et al. (2013) also did not observe the influence of the reducers on the number of grains per pod. Using the same regulator in soybeans, it was verified that plant dry mass, leaf area, production components and yield were not affected by the use of this plant growth reducer (LINZMEYER JUNIOR et al., 2008).

Trinexapac is an acylcyclohexanedione (Caldas et al., 2009; Rademacher, 2000) which, in Poaceae, such as wheat and rye, causes a reduction in node interlength and, consequently, in plant height. It is used to reduce plant lodging (MAPA, 2011; Espindula et al., 2009), but with no negative effect on grain yield (ZAGONEL; FERNANDES, 2007).

The results of this work corroborate those of Linzmeyer Junior et al. (2008), in which the application of the plant retardant directly influenced the height of soybean plants, with a decreasing linear effect for plant height when applying the retardant and the density of plants used. Similar results were obtained by Alvarez (2003), who, using trinexapac in rice cultivation, observed a reduction in plant height of up to 34 cm.

Zagonel (2007) found that wheat cultivars responded linearly to the dose of trinexapac, decreasing height with increasing dose of the reducer, except for the cultivar Onix, a result that corroborates other studies (Zagonel, 2003; Zagonel et al., 2005; Zagonel; Kunz, 2005), showing that the product is effective in reducing the height of wheat plants.

The final plant population depends on several factors, which include climatic conditions in the initial periods of crop development and the cultivars used. Plant density (cultivated and weeds) and even the positioning of the fertilizer distributed by the seeder can influence the development of the root system of cultivated plants. In addition to the processes involved in shoot growth, gibberellins are involved in root system stimulation and growth processes (BEVILAQUA et al., 1996). Thus, the non-significant result for this variable is explained.

In the present work, it was observed that the mass of 100 grains was not significantly affected by the treatments, however, the yield was significant (Table 4). Unlike the result of this work, Linzmeyer Junior et al. (2008) verified that the application of trinexapac-ethyl (100 g ha<sup>-1</sup>) in bean plants, cultivar Pérola, did not affect seed mass, number of seeds per plant, number of pods per plant and number of seeds per pod.

The increase in productivity was also noticed in the present experiment with the use of the growth regulator. According to Zagonel; Fernandes (2007), the use of trinexapac has been highlighted by its efficiency in reducing the height of plants and improving the leaf architecture of wheat and by increasing the stem diameter, reducing lodging and optimizing the use of solar radiation, with increased productivity.

In wheat, medium to small cultivars, although less responsive to trinexapac, can also have their grain yield maximized by better leaf architecture and radiation capture, by the increase in the number of fertile tillers and by the greater targeting of photoassimilates to grain production, to the detriment of stem development (ZAGONEL et al., 2002; MATYZIAK, 2006; ZAGONEL; FERNANDES, 2007).

Thus, growth regulators such as trinexapac can be used in soybean cultivars, in order to reduce plant lodging and, consequently, increase productivity. However, there is a certain lack of technical information when it comes to

Fabaceae, with some divergences between the results obtained. As it is a recommended growth regulator for grasses, there is no precision on such a regulator for other crops. Therefore, it is necessary to intensify research on this growth regulator, especially in soybean crops.

## 5. CONCLUSION

The application of growth regulator, regardless of time and dose, optimized the productive components of the soybean crop, cultivar BS 2606 IPRO, when compared to the absence of the growth regulator.

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