REVISTA DE CIÊNCIAS AGRÁRIAS
Amazonian Journal
of Agricultural and Environmental Sciences
www.ajaes.ufra.edu.br

ORIGINAL ARTICLE

Does growth regulator associated with fungicide interfere on productivity of upland rice?

Regulador de crescimento associado ao fungicida interfere na produtividade do arroz de terras altas?

Flávia Constantino Meirelles[1]*
Alex Rangel Gonzaga[1]
Orivaldo Arf[1]
José Roberto Portugal[1]
Amanda Ribeiro Peres Portugal[1]

[1]Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), Campus de Ilha Solteira, Rua Monção, 226, 15385-000, Ilha Solteira, SP, Brasil.

*** Autora correspondente:**
E-mail: flavia.meirelles1905@gmail.com

KEYWORDS
Oryza sativa L.
Epoxiconazole + pyraclostrobin
Ethyl-trinexapac
Lodging
Plants height

PALAVRAS-CHAVE
Oryza sativa L.
Epoxiconazol + piraclostrobina
Etil-trinexapac
Acamamento
Altura de plantas

ABSTRACT: Management measures should be tested to increase the rice productivity, a staple food that is in increasing demand. The aim of this study was to evaluate the efficacy of different doses of a plant growth regulator, ethyl-trinexapac, combined with the application of the fungicides epoxiconazole + pyraclostrobin in reducing the height of rice plants to avoid lodging and increase rice yield. The experiment was conducted in a dystrophic Oxisol soil during two harvests (2010/2011 and 2011/2012). The study was arranged in a randomized block design, in a 4 × 2 factorial scheme, with four replications. The factors considered were four doses of trinexapac- ethyl (0, 25, 50, and 75 g ha^{-1} active ingredient (a.i.)), with or without application of fungicide (137.25 g ha^{-1} a.i.). The growth regulator caused a reduction in plant height in both harvests and affected the number of panicles per square meter in the second harvest. The fungicide had no effect on the productivity and yield components of the crop.

RESUMO: *Medidas de gestão devem ser testadas para aumentar a produtividade do arroz, um alimento básico, que está em crescente demanda. O objetivo deste estudo foi avaliar a eficácia de diferentes doses de um regulador de crescimento de plantas, etil-trinexapac, combinado com a aplicação do fungicida, epoxiconazol + piraclostrobina, na redução da altura das plantas de arroz, para evitar o acamamento e aumentar o rendimento do arroz. O experimento foi conduzido em Latossolo Vermelho distrófico durante duas colheitas (2010/2011 e 2011/2012). O delineamento foi em blocos casualizados, em esquema fatorial 4 × 2, com quatro repetições. Os fatores considerados foram quatro doses de etil-trinexapac (0, 25, 50 e 75 g* ha^{-1} *de ingrediente ativo (a.i.)), com ou sem aplicação de fungicida (137,25 g* ha^{-1} *a.i.). O regulador de crescimento causou redução na altura das plantas nas duas safras e afetou o número de panículas por metro quadrado no segundo ano de cultivo. O fungicida não afetou os componentes de produtividade e rendimento da cultura.*

Received: 01/03/2020
Accepted: 17/08/2020

1 Introduction

Rice (*Oryza sativa* L.) is one of the main cereals consumed by humans and it is necessary to increase production of this crop to meet the increased demand, since the global population is estimated to reach 11.18 billion by the year 2100 (United Nations, 2017). To increase rice productivity management practices such as nitrogen (N) fertilization using high nitrogen doses have become common.

However, applying high doses of nitrogen to rice crops can increase the length of the internodes of the plants, resulting in lodging (Arf et al., 2015; Zhang et al., 2017), which consequently causes damage to crop productivity and grain quality. The use of growth regulators in rice crops allows for the successful application of nitrogen fertilization, avoiding the lodging of the plants. Trinexapac-ethyl is a growth regulator that inhibits the synthesis of gibberellin, and when absorbed by leaves is directed to growth points of plants inhibiting the internode elongation (Tomlin, 1995).

Another measure that can be adopted in order to increase rice productivity is the use of fungicides with a physiological effect, such as strobilurins. These fungicides may improve grain yield by increasing leaf chlorophyll content, leaf biomass, and leaf area (Soares et al., 2011; Bárányiová1 & Klem, 2016). However, there is a lack of information on effective application of growth regulator doses in rice cultivation, and the combined effect of applying growth regulators together with fungicides with physiological effects.

The work had as hypothesis the reduction of the plant's height with application of growth regulator, as well as the synergistic effect of the fungicide in the increase of grain yield.

Based on the above, the objective of this study was to evaluate the effect of different doses of growth regulator (trinexapac ethyl) and the application of a fungicide with physiological effects (epoxiconazole + pyraclostrobin) on lodging and productivity of upland rice under sprinkler irrigation.

2 Material and Methods

The experiment was conducted at São Paulo State University (UNESP), Ilha Solteira Campus, in the municipality of Selvíria, in Mato Grosso do Sul (MS), Brazil. The study site was located at 20º 22' S, 51° 22' W, at an altitude of 335 m a.s.l. The local soil is characterized as a typical clayey dystrophic Red Latosol (Embrapa, 2018).

The mean annual rainfall at the study site is 1,313 mm, with a maximum annual temperature of 31°C, and an annual minimum temperature of 19°C. The mean air relative humidity is between 70 and 80% (Portugal et al., 2015).

The experiment was conducted during two harvests, namely those of 2010/11 and 2011/12. Daily data on precipitation, and maximum and minimum air temperature were recorded during the first (Figure 1) and second harvest (Figure 2) during which the experiment was conducted.

The experimental design was a randomized block design in a 4 × 2 factorial scheme with four replications. The plots consisted of six lines of 5 m in length. We considered the two central lines as the useable area, and excluded the external lines.

The treatments consisted of the application of four doses of trinexapac-ethyl growth regulator (0, 25, 50, and 75 g ha^{-1} a.i.), combined with either fungicide application (epoxiconazole + pyraclostrobin at a dose of 137.25 g ha^{-1} a.i.) or without fungicide application. The products were utilized 20 days after floral differentiation. Growth regulator and fungicide were applied as 400 L ha^{-1} spray, using a knapsack sprayer with manual TX-conical beak. Growth regulator and fungicide were applied between 9 and 10 a.m, in order to avoid drift and provide adequate absorption by plants (Antuniassi & Boller, 2019).

Chemical analysis of the soil in the 0-0.20 m layer was conducted prior to the study, with the following results: pH ($CaCl_2$), 5.5; organic matter, 19 g dm^{-3}; P (resin), 35 mg dm^{-3}; K, Ca, Mg and potential acidity (H + Al), 1.7;

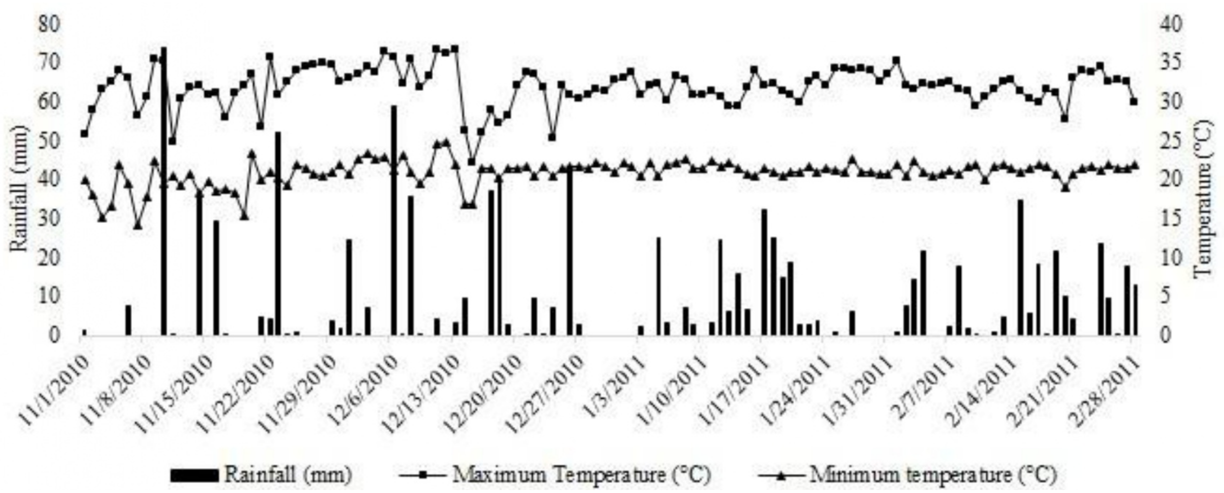

Figure 1. Data of rainfall (mm), and maximum and minimum air temperatures (°C) in Selvíria, MS, Brazil, from November 2010 to February 2011.

Figura 1. Dados de precipitação (mm), temperaturas máxima e mínima (°C) em Selvíria, MS, Brasil, de novembro de 2010 a fevereiro de 2011.

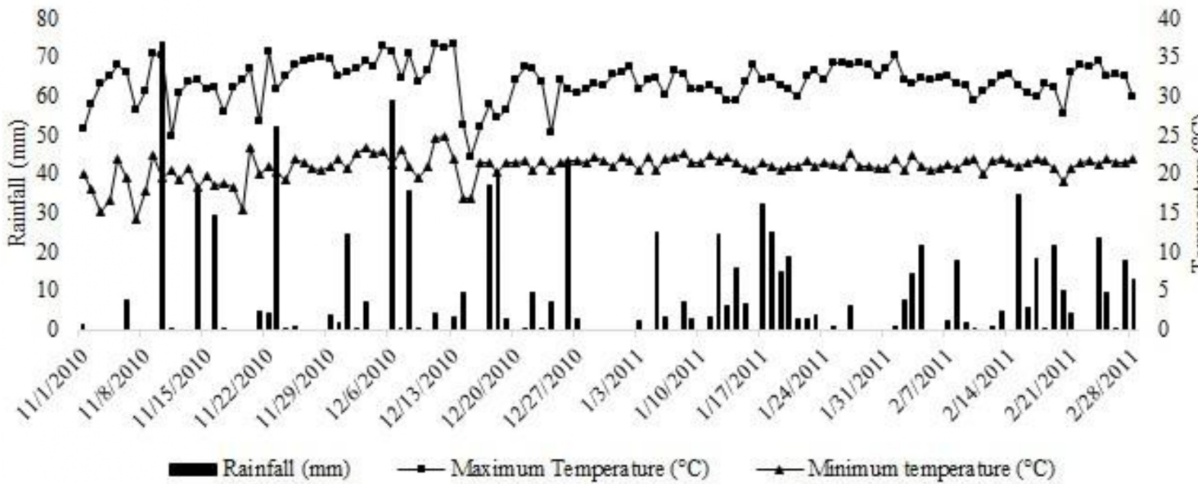

Figure 2. Data of rainfall (mm), and maximum and minimum air temperatures (°C) in Selvíria, MS, Brazil, from November 2011 to February 2012.

Figura 2. Dados de precipitação (mm), temperaturas máxima e mínima (°C) em Selvíria, MS, Brasil, de novembro de 2011 a fevereiro de 2012.

21; 11 and 20 mmol, dm^{-3}, respectively; and base saturation was 63%.

Soil preparation before rice implantation was performed with a disk plow and an intermediate harrow and leveling harrow in the two years of cultivation. Sowing fertilization was done with application of 180 kg ha^{-1} of formulation 08-28-16 in the sowing furrow. Prior to sowing, the seeds were treated with fipronil (50 g active ingredient (a.i.) 100 kg^{-1} seed).

The rice was sown on November 4th, 2010 and on November 8th, 2011, for the first and second crops, respectively. A density of 75 seeds m^{-1} of the BRS Primavera cultivar, spaced 0.35 m between rows, was used. Seedling emergence occurred six days after sowing in the first and second year. The application of top-dressing nitrogen was performed at 70 kg ha^{-1} using ammonium sulfate 30 days after emergence (DAE).

Rice irrigation was performed using a conventional sprinkler system with a mean precipitation of 3.3 mm h^{-1}. Three crop coefficients (Kc) were used in the water management divided into four periods and distributed between emergence and harvest. At the vegetative stage a Kc value of 0.4 was used; at the reproductive stage two values of Kc were used, including an initial value of 0.70 and a final value of 1.00; and in the maturing stage the values of the reproductive stage were reversed, such that a Kc value of 1.00 was used at the beginning, and a Kc value of 0.70 was used at the end.

Weeds were controlled by hand weeding and harvesting was done manually. After drying the grains, the filled and unfilled grains were separated by air flow.

The following variables were analyzed: height of the plant - measured in the phase of pasty grains as the distance from the soil surface to the upper extremity of the highest panicle at five points per plot; panicles m^{-2} – measured as the panicle count at 1.0 m in the usable area and subsequently calculated per square meter; total grains – measured as the average grain count of 20 panicles collected at the time of harvest, on each plot; filled and unfilled grains per panicle – measured as the average number of filled and unfilled grains of 20 panicles after separation by air flow.

Other evaluations were also performed as100 grain mass - measured by randomly sampling and weighing a sample of 100 grains of each plot (13% wet basis); hectoliter mass - measured on a special scale for hectoliter mass, using two samples per plot; productivity - determined by weighing the grains from the useful area of the plots, correcting the humidity to 13% and converting to kg ha^{-1}; milling yield, head rice yield, and proportion of broken grains – to measure these variables, a 100 g sample of rice grains (paddy) from each plot was processed, hulled rice grains were obtained, grains were submitted to a test mill for 1 minute, and subsequently the polished grains were weighed, and the resulting value was used as the milling yield. Subsequently, the polished grains were placed in a Trieur machine for 30 seconds, to separate the grains. The grains remaining in the Trieur machine were weighed, obtaining the head grain yield and the remaining broken grains. All results are expressed as a percentage.

Data were submitted to analysis of variance (ANOVA). When significant results were found by applying the F test, data on the different growth regulator doses were submitted to regression analysis.

3 Results and Discussion

An effect of different doses of growth regulator on plant height (Table 1) was observed, and the data followed a linear pattern in the first and second crop years (Figure 3 (a, b)). There was a reduction in plant height with an increase in trinexapac-ethyl dose.

Trinexapac-ethyl is a growth regulator that interacts in an antagonistic way with the production of gibberellin (Rodrigues & Fioreze, 2015), which results in plants with short stems (Taiz al., 2017). Gibberellic acid stimulates plant growth by converting GA20 to GA1, and trinexapac-ethyl inhibits gibberellic acid by blocking 3β-hydroxylase, preventing the conversion of GA20 to GA1 (Wang et al., 2009).

Table 1. Plant height and number of panicles m^{-2} of upland rice irrigated by sprinklers in Selvíria, MS, Brazil, in 2010/11 and 2011/12, and treated with different doses of growth regulator (0, 25, 50, and 75 g ha^{-1}) and fungicide (0 and 137.25 g ha^{-1}).

Tabela 1. Altura de plantas e número de panículas m^{-2} de arroz de terras altas irrigado por aspersão em Selvíria, MS, Brasil, em 2010/11 e 2011/12, tratado com diferentes doses de regulador de crescimento (0, 25, 50, e 75 g ha^{-1}) e fungicida (0 e 137,25 g ha^{-1}).

Treatments	Plants height (cm)		Panicles m^{-2} (number)	
	2010/11	2011/12	2010/11	2011/12
Doses of Growth Regulator				
0	102.9 (1)	105.8 (2)	146	302(3)
25	101.2	98.8	151	282
50	96.7	93.3	133	267
75	93.05	86.2	156	247
Fungicide application				
With	97.6	96.0	142	274
Without	99.4	96.1	151	275
F test				
Doses	15.82 **	7.55 **	1.94 ^{ns}	7.56 **
Fungicide	2.36 ^{ns}	0.00 ^{ns}	1.63 ^{ns}	0.00 ^{ns}
D x F	0.72 ^{ns}	0.58 ^{ns}	0.84 ^{ns}	0.62 ^{ns}
CV (%)	3.11	7.74	13.71	7.65

*p≤0.05, **p≤0.01, ^{ns} no significant by the F test (p<0.05). CV: coefficient of variation.

In comparison to the control (no trinexapac-ethyl applied), the highest dose of trinexapac-ethyl (75 g ha^{-1} a.i) resulted in a reduction in plant height by 9.9 and 19.6 cm for the first and second crops, respectively. In a study by Arf et al. (2012) lodging was observed in the cultivars BRS Primavera, BRS Soberana, and Caiapó when plant height exceeded 1.20 m. In the present study, there was no lodging of plants in any of the treatments, as the height of the plants did not exceed 1.06 m, even in the control treatment (i.e. no application of growth regulator). However, in situations of high soil fertility and high doses of applied nitrogen, the rice plant becomes more susceptible to lodging, which is harmful at the time of harvest.

The application of fungicide did not affect the height of rice plants. This is in agreement with Francischini et al. (2018), who evaluated the effects of applying epoxiconazole + pyraclostrobin at a dose of 0.75 L ha^{-1} on sweet corn plants, and did not find differences in plant height between plants treated or not treated with fungicide. Although the fungicide did not affect plant height, there are indications that the fungicide has a negative effect on the synthesis of ethylene by plants, so the plants may have leaves that remain green for a longer period, which helps plants avoid lodging providing a good “stay green” to the plants (Lopes et al., 2018).

Regarding the number of panicles m^{-2} there was no effect of growth regulator doses and/or fungicide application in the first crop year. In the second year there was a reduction in the number of panicles m^{-2} with increasing doses of trinexapac-ethyl (Figure 4). This is in agreement with Alvarez et al. (2014), who evaluated three growth regulators (trinexapac-ethyl, paclobutrazol, and mepiquat chloride), all of which decreased the number of panicles m^{-2} when the applied dose increased.

Grohs et al. (2012) found an increase in the number of panicles when gibberellic acid was applied in two cultivars of irrigated rice, indicating that this hormone is important in the formation of panicles. Thus, the use of a gibberellin inhibitor may have affected this characteristic.

There was no effect of growth regulator doses and/or fungicide application on the amount of total grains, or on the filled and unfilled grains per panicle (Table 2). However, the application of trinexapac-ethyl at the beginning of tillering, may result in greater fertility of spikelets in relation to application during floral differentiation (Alvarez et al., 2012). This phenomenon occurs because trinexapac-ethyl also interferes with the branching of the rachis and the formation of the spikelets through branching (Alvarez et al., 2007).

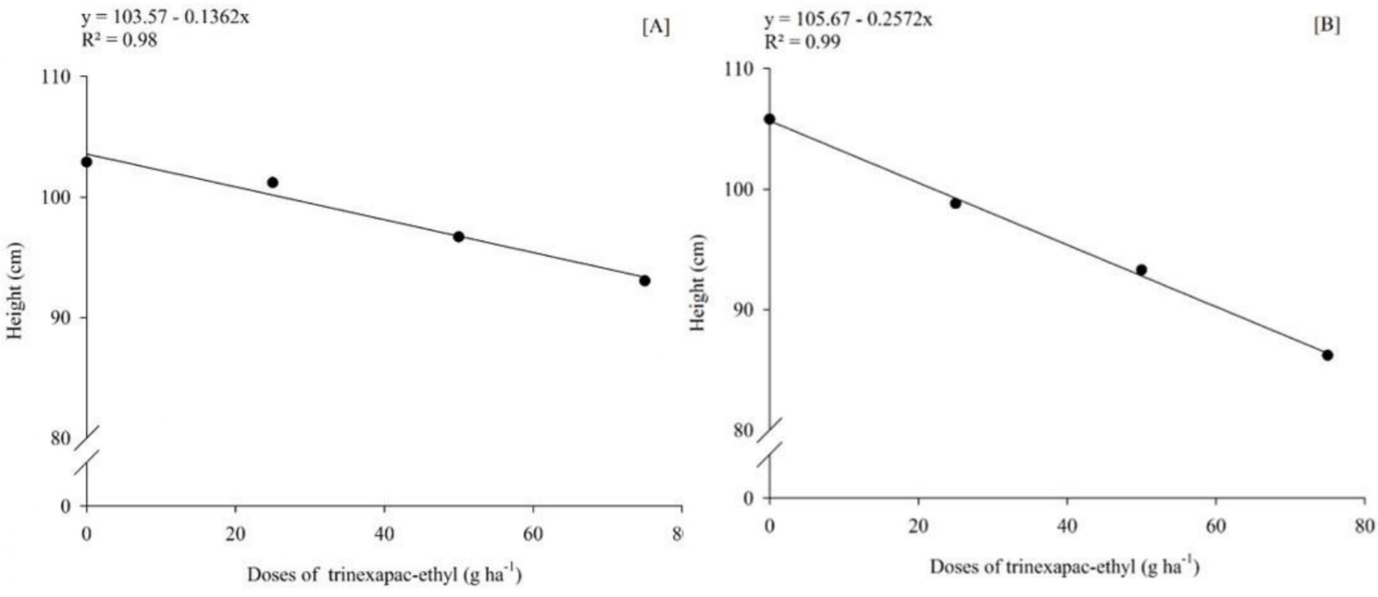

Figure 3. Plant height as a function of trinexapac-ethyl doses (0, 25, 50, and 75 g ha^{-1} a.i) in the 2010/11 (A) and 2011/12 (B) rice crops in Selvíria, MS, Brazil.

Figura 3. Altura de plantas em função de doses de etil-trinexapac (0, 25, 50, e 75 g ha^{-1}) de arroz nas safras 2010/11 (A) e 2011/12 (B) em Selvíria, MS, Brasil.

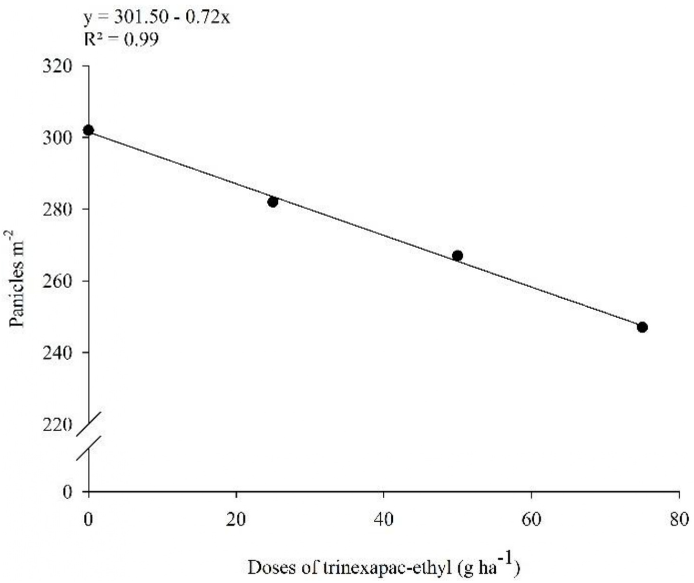

Figure 4. Panicles m^{-2} of rice plants in Selvíria, MS, Brazil, treated with different doses of trinexapac-ethyl (0, 25, 50, and 75 g ha^{-1}) during the 2011/12 harvest season.

Figura 4. Panículas m^{-2} de plantas de arroz em Selvíria, MS, Brasil, tratadas com diferentes doses de etil-trinexapac (0, 25, 50, e 75 g ha^{-1}) durante a safra 2011/12.

Our results are also in agreement with those of Fiallos and Forcelini (2011), who did not observe an effect of epoxiconazole + pyraclostrobin, and tebuconazol application on the quantity of grains, per soybean plant.

Table 2. Total grains, filled grains, and unfilled grains per panicle of upland rice irrigated by sprinklers in Selvíria, MS, Brazil, in 2010/11 and 2011/12, and treated with different doses of growth regulator (0, 25, 50, and 75 g ha^{-1}) and fungicide (0 and 137.25 g ha^{-1}).

Tabela 2. Grãos totais, grãos cheios e grãos chochos por panícula em arroz de terras altas irrigado por aspersão em Selvíria, MS, Brasil, em 2010/11 e 2011/12, tratado com diferentes doses de regulador de crescimento (0, 25, 50, e 75 g ha^{-1}) e fungicida (0 e 137,25 g ha^{-1}).

Treataments	Total grains		Filled grains		Unfilled grains	
	2010/11	2011/12	2010/11	2011/12	2010/11	2011/12
Doses of Growth Regulator						
0	170	163	138	128	32	35
25	164	170	136	135	28	34
50	159	154	128	126	31	28
75	163	176	136	147	27	29
Fungicide application						
With	164	169	133	135	31	34
Without	164	162	135	133	28	29
F test						
Doses	0.35 ^{ns}	1.52 ^{ns}	0.31 ^{ns}	1.63 ^{ns}	0.73 ^{ns}	2.31 ^{ns}
Fungicide	0.00 ^{ns}	0.94 ^{ns}	0.08 ^{ns}	0.13 ^{ns}	0.72 ^{ns}	3.22 ^{ns}
D x F	0.69 ^{ns}	2.56 ^{ns}	0.43 ^{ns}	2.84 ^{ns}	0.26 ^{ns}	0.03 ^{ns}
CV (%)	13.57	11.19	17.04	13.45	28.84	19.49

*p≤0.05, **p≤0.01, ^{ns} no significant by the F test (p<0.05). CV: coefficient of variation.

We expected that our growth inhibitor and epoxiconazole + pyraclostrobin treatments would affect the amount of grain per panicle, grain mass, and rice yield, as this fungicide can promote greater green mass production, which results in a higher photosynthetic rate by the plants (Lopes et al., 2018), which in turn affects grain filling and productivity. In addition, under conditions of water stress, pyraclostrobin assists in the elimination of reactive oxygen species, improving the performance of plants subjected to this stress (Jadoski, 2015). However, in the current study, water was supplied using a sprinkler system, so plants were not subjected to water stress, which may have minimized the effect of the fungicide under the conditions of our study.

There was no difference in the 100 grain mass, hectoliter mass, and grain yield in treatments using different doses of trinexapac-ethyl and epoxiconazole + pyraclostrobin (Table 3). Nunes et al. (2016) used five doses of trinexapac-ethyl (0, 0.2, 0.4, 0.6, and 0.8 L ha^{-1}), and did not find an effect on grain mass and wheat yield. The 100 grain mass was similar in the two years of cultivation, due to the grain size being determined by the bark, which is a varietal characteristic (Yoshida, 1981).

Table 3. One hundred grain mass (mass 100), hectoliter mass (Mass hect) and grain yield (Yield) of upland rice irrigated by sprinklers in Selvíria, MS, Brazil, in 2010/11 and 2011/12, treated with different doses of growth regulator (0, 25, 50, and 75 g ha^{-1} a.i) and fungicide (0 and 137.25 g ha^{-1}).

Tabela 3. Massa de cem grãos (Mass 100), massa hectolítrica (Mass hect) e produtividade de grãos (Yield) de arroz de terras altas em Selvíria, MS, Brasil, em 2010/11 e 2011/12, tratado com diferentes doses de regulador de crescimento (0, 25, 50, e 75 g ha^{-1}) e fungicida (0 e 137,25 g ha^{-1}).

Treatments	Mass 100 (g)		Mass hect. (kg hl^{-1})		Yield (kg ha^{-1})	
	2010/11	2011/12	2010/11	2011/12	2010/11	2011/12
Doses of Growth Regulator						
0	2.5	2.7	45.6	55.7	3.431	4.470
25	2.5	2.9	43.8	54.1	3.271	4.658
50	2.5	2.7	44.9	55.1	3.451	4.931
75	2.6	2.8	47.1	54.7	3.934	4.516
Fungicide application						
With	2.5	2.7	44.9	54.8	3.401	4.495
Without	2.5	2.8	45.8	55.0	3.643	4.793
F test						
Doses	0.49 ^{ns}	0.45 ^{ns}	2.08 ^{ns}	0.60 ^{ns}	1.66 ^{ns}	0.61 ^{ns}
Fungicide	0.29 ^{ns}	0.83 ^{ns}	0.83 ^{ns}	0.02 ^{ns}	1.19 ^{ns}	1.26 ^{ns}
D x F	0.26 ^{ns}	0.80 ^{ns}	0.53 ^{ns}	0.44 ^{ns}	0.12 ^{ns}	0.35 ^{ns}
CV(%)	10.49	10.13	6.03	3.74	17.83	14.02

*p≤0.05, **p≤0.01, ^{ns} no significant by the F test (p<0.05). CV: coefficient of variation.

In the present study, although there was a reduction in the number of panicles m^{-2} with increasing doses of growth regulator, in the second year of cultivation, this did not cause a reduction in grain yield. A higher grain yield was observed in the second year of cultivation compared to the first, which was due to the higher number of panicles m^{-2}, a greater 100 grain mass, and a higher hectoliter mass obtained in the second year. The higher values in the 2011/12 harvest are likely related to the higher occurrence of global radiation and net radiation in this crop (2,712.9 and 1,607.3 MJ m^{-2} day^{-1}, respectively) in relation to the 2010/11 crop (2,552.5 and 1,408.6 MJ m^{-2} day^{-1}, respectively). The energy supplied by light is fundamental for the photosynthetic process, since light energy stimulates the production of sugars from carbon dioxide and water, and the release of oxygen. In addition, light regulates the enzyme activity of the Calvin-Benson cycle, including that of rubisco (Taiz et al., 2017).

There was no effect of the application of trinexapac-ethyl and epoxiconazole + pyraclostrobin on milling yield, head grain yield, nor the proportion of broken grains (Table 4). In the second year of cultivation (2011/2012), higher values of milling yield and head yield, and lower proportions of broken grains were observed. This is likely due to the greater sum of the global radiation rate during the grain filling stage in the 2011/12 crop (676.0 MJ m^{-2} day^{-1}) compared to the 2010/11 crop (634.4 MJ m^{-2} day^{-1}), as solar radiation is the main meteorological factor that influences rice grain yield in the reproductive and grain-filling phases (Ribas et al., 2016).

Table 4. Milling yield (MY), head grain yield (HG), and proportion of broken grains (BG) of upland rice irrigated by sprinklers in Selvíria, MS, Brazil, in 2010/11 and 2011/12, and treated with different doses of growth regulator (0, 25, 50, and 75 g ha^{-1}) and fungicide (0 and 137.25 g ha^{-1}).
Tabela 4. Rendimento de engenho (MY), grãos inteiros (HG) e proporção de grãos quebrados (BG) de arroz de terras altas em Selvíria, MS, Brasil, em 2010/11 e 2011/12, tratado com diferentes doses de regulador de crescimento (0, 25, 50, e 75 g ha^{-1}) e fungicida (0 e 137,25 g ha^{-1}).

Treatments	MY (%)		HG (%)		BG (%)	
	2010/11	2011/12	2010/11	2011/12	2010/11	2011/12
Doses of Growth Regulator						
0	68.2	74.8	55.4	71.0	12.4	3.8
25	65.9	75.1	53.8	71.2	11.9	4.0
50	68.2	74.0	59.3	70.2	8.8	3.8
75	68.2	73.7	57.5	69.7	10.6	3.9
Fungicide application						
With	67.3	73.9	56.5	69.8	10.5	4.1
Without	67.9	74.9	56.4	71.2	11.4	3.7
F test						
Doses	0.52 ^{ns}	0.85 ^{ns}	1.33 ^{ns}	0.55 ^{ns}	1.86 ^{ns}	0.07 ^{ns}
Fungicide	0.18 ^{ns}	1.74 ^{ns}	0.00 ^{ns}	2.04 ^{ns}	0.61 ^{ns}	1.85 ^{ns}
D x F	0.76 ^{ns}	0.17 ^{ns}	1.10 ^{ns}	0.14 ^{ns}	1.86 ^{ns}	0.34 ^{ns}
CV(%)	6.77	2.37	10.42	3.24	30.54	21.19

*p≤0.05, **p≤0.01, ^{ns} no significant by the F test (p<0.05). CV: coefficient of variation.

According to the Brazilian Normative Instruction of the Ministry of Agriculture, Livestock and Supply (Brazil, 2010), it is possible to classify the type of grain according to the proportion of broken grains. The classification ranges from 1 to 5, where 1 indicates the best quality rice, with the lowest proportion of broken grains, and 5 indicates a lower quality rice, with the highest proportion of broken grains.

In this experiment, the proportions of broken grains in the first harvest were between 7.5 and 15%, which corresponds to a type 2 classification. In the second year of cultivation, the proportion of broken grains was 7.5%, and as such, the rice could be classified as type 1.

4 Conclusion

The trinexapac-ethyl growth regulator reduces plant height without negatively affecting rice grain yield. Application of epoxiconazole + pyraclostrobin fungicide does not affect the production components and the grain yield of sprinkler irrigated upland rice.

References

ALVAREZ, R. C. F.; CRUSCIOL, C. A. C.; RODRIGUES, J. D.; ALVAREZ, A. C. C. Aplicação de reguladores vegetais na cultura de arroz de terras altas. *Acta Scientiarum. Agronomy*, v. 29, n. 2, p. 241-249, 2007.

ALVAREZ, R. C. F.; CRUSCIOL, C. A. C.; NASCENTE, A. S.; RODRIGUES, J. D.; HABERMANN, G. Gas exchange rates, plant height, yield components, and productivity of upland rice as affected by plant regulators. *Pesquisa Agropecuária Brasileira*, v. 47, n. 10, p. 1455-1461, 2012.

ALVAREZ, R. C. F.; CRUSCIOL, C. A. C., NASCENTE, A. S. Produtividade de arroz de terras altas em função de reguladores de crescimento. *Revista Ceres*, v. 61, n. 1, p. 42-49, 2014.

ANTUNIASSI, U. R.; BOLLER, W. Tecnologia de aplicação para fungicidas. In: ANTUNIASSI, U. R.; BOLLER, W (Eds.). *Tecnologia de aplicação para culturas anuais*. 2 ed. Passo Fundo: Aldeia Norte. Botucatu: FEPAF, p.283-300, 2019.

ARF, O; NASCIMENTO, V.; RODRIGUES, R. A. F.; ALVARES, R. C. F.; GITTI, D. C.; SÁ, M. E. Uso de etil-trinexapac em cultivares de arroz de terras altas. *Pesquisa Agropecuária Tropical*, v. 42, n. 2, p. 150-158, 2012.

ARF, O.; RODRIGUES, R. A. F.; NASCENTE, A. S.; LACERDA, M. C. Adubação antecipada de nitrogênio na cultura do arroz de terras altas sob plantio direto. *Revista Ciências Agrárias*, v. 58, n. 1, p. 6-13, 2015.

BARÁNTIOVÁ, I.; KLEM, K. Effect of application of growth regulators on the physiological and yield parameters of winter wheat under water deficit. *Plant, Soil and Environment*, v. 62, n. 3, p. 114-120, 2016.

BRAZIL. Ministry of Agriculture, Livestock and Supply. Normative instruction, 12, *Diário Oficial da República Federativa do Brasil*, Brasília, DF, March, 12, 2010.

EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária). *Sistema brasileiro de classificação de solos*. Brasília-DF: Centro Nacional de Pesquisa de Solos – CNPS, 2018. 356 p.

FIALLOS, F. R. G.; FORCELINI, C. A. Progresso temporal da ferrugem e redução sobre a área foliar e os componentes do rendimento de grãos em soja. *Acta Agronómica*, v. 60, n. 2, p. 147-157, 2011.

FRANCISCHINI, R.; SILVA, A. G.; TESSMANN, D. J.

Eficiência de bioestimulantes e fungicida nos caracteres agronômicos e econômicos na cultura do milho verde. *Revista Brasileira de Milho e Sorgo*, v. 17, n. 2, p. 274-286, 2018.

GROHS, M.; MARCHESAN, E.; ROSO, R.; FORMENTINI, T. C.; OLIVEIRA, M. L. Desempenho de cultivares de arroz com uso de reguladores de crescimento, em diferentes sistemas de cultivo. *Pesquisa Agropecuária Brasileira*, v. 47, n. 6, p. 776-783, 2012.

JADOSKI, C. J.; RODRIGUES, J. D.; SORATTO, R. P.; SANTOS, C. M.; RIBEIRO, E. Ação fisiológica da piraclostrobina na assimilação de CO2 e na atividade de enzimas antioxidantes em plantas de feijão em diferentes tensões de água no solo. *Irriga*, v. 20, n. 2, p. 319-333, 2015.

LOPES, A. M.; SCHUMACHER, P. V.; MARTÍNEZ, A. T. P.; NETTO, A. P. C.; CHALFUN-JUNIOR, A. Insights into the positive effect of pyraclostrobin on sugarcane productivity. *Agronomy*, v. 8, n. 7, p. 1-11, 2018.

NUNES, P. H. M. P.; AQUINO, L. A.; XAVIER, F. O.; SANTOS, L. P. D.; MACHADO, L. G.; AQUINO, P. M. Regulador de crescimento e nitrogênio no desempenho produtivo e acamamento do trigo irrigado. *Semina: Ciências Agrárias*, v. 37, n. 4, p. 1709-1720, 2016.

PORTUGAL, J. R.; PERES, A. R.; RODRIGUES, R. A. F. Aspectos climáticos no feijoeiro. In: ARF, O.; LEMOS, L.B.; SORATTO, R. P.; FERRARI, S (Eds.). *Aspectos gerais da cultura do feijão Phaseolus vulgaris L.* Botucatu: FEPAF. 2015, p. 65-75.

RIBAS, G. G.; STRECK, N. A.; LAGO, I.; ZANON, A. J.; WALDOW, D. A. G.; DUARTE JUNIOR, A. J.; NASCIMENTO, M. F.; FONTANA, V. Acúmulo de matéria seca e produtividade em híbridos de arroz irrigado simulados com o modelo SimulArroz. *Pesquisa Agropecuária Brasileira*, v. 51, n. 12, p. 1907-1917, 2016.

RODRIGUES, J. D.; FIOREZE, S. L. Reguladores são, para muitos cultivos, indispensáveis ao alcance de bons níveis. *Visão Agrícola*, v. 13, p. 35-39, 2015.

SOARES, L. H.; FAGAN, E. B.; CASAROLI, D.; ANDRADE, D. M.; SOARES, A. L.; MARTINS, K. V.; ROCHA, F. J. Aplicação de diferentes estrobilurinas na cultura da soja. *Revista da Faculdade de Zootecnia, Veterinária e Agronomia*, v. 18, n. 1, p. 78-97, 2011.

TAIZ, L.; ZEIGER, E.; MØLLER, I. A.; MURPHY, A. *Fisiologia e Desenvolvimento Vegetal*, 6th ed. Porto Alegre: Artmed, 2017. 858 p.

TOMLIN, C. *The pesticide manual handboock*, 10th ed. London: British Crop Protection Council, 1995. 1341 p.

UNITED NATIONS, Department of Economic and Social Affairs, Population Division. *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables*. 2017 Available at: https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf Accessed 13 September 2019.

WANG, X.; HU, T.; WANG, Q.; TIAN, L.; ZHANG, X.; TIAN, K. Growth of kentucky bluegrass as influenced by nitrogen and trinexapacethyl. *Agricultural Sciences in China*, v.8, n. 12, p. 1498-1502, 2009.

YOSHIDA, S. *Fundamentals of rice crop science*. Los Baños: IRRI, 1981. 269 p.

ZHANG, M.; WANG, H.; YI, Y.; DING, J.; ZHU, M.; LI, C.; GUO, W.; FENG, C.; ZHU, X. Effect of nitrogen levels and nitrogen ratios on lodging resistance and yield potential of winter wheat (*Triticum aestivum L.*). *Plos One*, v. 12, n. 11, p. 1-12, 2017.

Author's contribution: Flávia Constantino Meirelles – data analysis and scientific writing; Alex Rangel Gonzaga – carrying out the experiment, collecting and analyzing data; Orivaldo Arf – guidance on the field experiment, data analysis and scientific writing; José Roberto Portugal – data collection and field development; Amanda Ribeiro Peres Portugal – scientific writing.

Acknowledgments: The authors thank the CNPq (Brazilian National Research Council) for financial support. authors.

Financial sources: There was no funding.

Declaration of interest: The authors declare no conflict of interest.