


DOI: <https://doi.org/10.17921/1415-6938.2026v30n1p59-75>


Fungicide Efficiency in Controlling Target Spot in Cotton Crops in the Brazilian Cerrado
Eficiência de Fungicidas no Controle de Mancha-Alvo na Cultura do Algodoeiro no Cerrado Brasileiro

Received on: February, 3, 2026

Accepted on: March, 25, 2026


Marcus Vinicius Gonçalves Lima: Universidade Anhanguera, Campus Tangará da Serra. MT, Brazil.
E-mail: marcus.lima@kroton.com.br 

José Victor Ramos de Almeida: Universidade Estadual do Mato Grosso. MT, Brazil. 

Roberto Antônio Savelli Martinez: Universidade Estadual do Mato Grosso. MT, Brazil. 

Ronicely Pereira da Rocha: Universidade Estadual do Mato Grosso. MT, Brazil. 

Adalberto Santi: Universidade Estadual do Mato Grosso. MT, Brazil. 

Marcio Osvaldo Lima Magalhães: Universidade Estadual do Mato Grosso. MT, Brazil. 

Rivanildo Dallacort: Universidade Estadual do Mato Grosso. MT, Brazil. 

Abstract

Foliar diseases, such as target spot, represent a major obstacle to cotton productivity, and inadequate management can favor the emergence of pathogens resistant to the active ingredients used to control them. The objective of this study was evaluate the effects of the application of fungicides based on prothioconazole, tebuconazole, fluxapyroxad, and pyraclostrobin on agronomic performance and disease control in cotton cultivation. A randomized block design with eight treatments and four replicates was used. Assessments were made of disease severity, phytotoxicity, percentage of defoliation, green leaf area, area under the disease progression curve, relative increase, and yield. No phytotoxicity was observed at the tested doses. Twenty-one days after the third application, there was a substantial increase in target spot severity in the control, with severity above 42.46%. Fungicide use was effective, with control ranging from 44.12% to 8.24%. There was a significant difference between treatments for the yield variable, with the Prothioconazole + Tebuconazole treatment, at a dose of 1 L ha⁻¹, showing the greatest relative increase in yield. The treatments were effective in reducing target spot disease compared to the control, with severity ranging from 44.12% to 68.24%. It is concluded that the use of Prothioconazole + Tebuconazole (1.0 L ha⁻¹) achieves better performance for the cotton crop, with a yield of 4.95 tons ha⁻¹ and a relative yield increase of 22.01%, in addition to lower severity values and greater control efficiency, constituting an alternative for target spot control.

Keywords: *Corynespora cassiicola*. Fluxapyroxad. Prothioconazole. Piraclostrobin. Tebuconazole.

Resumo

As doenças foliares, como a mancha-alvo, representam um dos principais entraves à produtividade da cultura do algodoeiro e o manejo inadequado dessas, pode favorecer o surgimento de patógenos resistentes aos princípios ativos utilizados em seus controles. Objetivou-se assim, avaliar os efeitos da aplicação de fungicidas à base de Prothioconazol, Tebuconazol, Fluxapiróxade e Piraclostrobina sobre o desempenho agrônômico e o controle de doenças na cultura do algodoeiro. O delineamento utilizado foi em blocos casualizados com 8 tratamentos e 4 repetições. Foram realizadas avaliações de severidade, fitotoxicidade, porcentagem de desfolha, área de folha verde, área abaixo da curva de progressão da doença; incremento relativo e produtividade. Não foi observado a presença de fitotoxicidade nas doses testadas. Aos 21 dias após a terceira aplicação houve aumento substancial da mancha alvo na testemunha, com severidade acima de 42,46%, onde o uso de fungicidas foi eficiente, com controle de 44,12% a 8,24%. Houve diferença significativa entre os tratamentos para a variável de produtividade, com destaque para o tratamento Prothioconazole + Tebuconazole, na dose de 1 L ha⁻¹, o qual obteve o maior incremento relativo de produtividade. Os tratamentos foram efetivos na redução de mancha-alvo em relação a testemunha com controle variando de 44,12% a 68,24% para severidade. Conclui-se que com o uso de Prothioconazole + Tebuconazole (1,0 L ha⁻¹) obtém melhor desempenho para a cultura do algodoeiro, com produtividade de 4,95 ton ha⁻¹ e incremento relativo de produtividade de 22,01%, além de menores valores de severidade e maior eficiência de controle, sendo uma alternativa para o controle de mancha-alvo.

Palavras-chave: *Corynespora cassiicola*. Fluxapiróxade. Prothioconazole. Piraclostrobina. Tebuconazole.

1 Introduction

The Brazilian Cerrado accounts for approximately 24% of the national territory, covering an area of 203.4 million hectares in the central region of Brazil (Marques *et al.*, 2024), and corresponds to about 50% of the country's agricultural area, with the cultivation of crops such as soybean, maize, sugarcane, and cotton.

Currently, it is the largest cotton-producing region in the country, representing between 95 and 98% of national production (Vilela *et al.*, 2020). Cotton was introduced into this biome in the early 1980s, driven by the need for an alternative crop in rotation with soybean, especially in areas affected by cyst nematodes (Bélot *et al.*, 2016). Alcantara *et al.* (2021) report that approximately 85% of Brazilian cotton is grown as a second crop, with emphasis on the state of Mato Grosso, which has become the largest producer of cotton lint in Brazil.

According to Melo and Bellen (2022), cotton production in the Cerrado region will certainly continue to be an important driver of agricultural economic growth in Brazil in the coming years. However, the crop is currently strongly affected by foliar diseases such as ramularia leaf spot and target spot.

Inadequate or inefficient management of these diseases may lead to pathogen resistance to active ingredients and cause drastic reductions in crop productivity (Cia *et al.*, 2020). Fungicides remain the predominant resource for effective control of such diseases, and up to eight sequential applications may be required during the crop cycle.

Galbieri *et al.* (2023) report that in the state of Mato Grosso, the 2022–2023 growing season

was marked by high rainfall levels, particularly between February and April. The high rainfall during this period resulted in increased average productivity and promoted greater plant tolerance to soilborne pathogens. Conversely, it favored the occurrence of diseases in the aerial parts of the plants, especially target spot (*Corynespora cassiicola*).

Sacon *et al.* (2024) state that the higher incidence of symptoms in the aerial parts of plants reported during the 2022/23 season may have been caused by the predominance of conditions and environments that favored significant disease development, directly linked to failures in disease control strategies, which typically prioritize ramularia leaf spot (*Ramularia areola*).

The management of target spot, as well as other fungal diseases occurring in cotton crops, can be achieved through the integration of several control measures, including: elimination of cotton plants during the sanitary fallow period; destruction of ratoons and volunteer plants that may serve as hosts for pathogens; selection of the most appropriate sowing time; adoption of wider row spacing; and efficient use of growth regulators (Brent; Hollomon, 2007; Lopes *et al.*, 2017).

Sacon *et al.* (2024) emphasize the importance of adopting resistant cultivars, continuous monitoring of the pathogen and the disease, and the implementation of a chemical control system based on the diversification of fungicide modes of action and the inclusion of multisite fungicides.

The use of fungicides with different sites of action is a practice that minimizes the effects of disease resistance to chemical molecules (Marques *et al.*, 2024), and the combination of chemical groups such as triazoles, carboxamides, and strobilurins is widely employed in integrated disease management (Lopes *et al.*, 2017).

The application of multisite fungicides with proven efficiency in controlling fungal diseases represents an important strategy in fungal management, promoting greater longevity of technologies and active ingredients, hindering pathogen resistance, and thus ensuring the economic and environmental sustainability of cotton production, enabling higher yields under Cerrado conditions in Mato Grosso (Galbieri *et al.*, 2021).

However, a reduction in pathogen sensitivity to different active ingredients registered for disease control in cotton (strobilurins, carboxamides, and benzimidazoles) has been observed. In this context, triazoles—specifically prothioconazole—and multisite fungicides play a predominant role in disease reduction (Sacon *et al.*, 2024).

As observed by Godoy *et al.* (2023), average results indicate a progressive decline in the efficacy of products containing mixtures associated with prothioconazole, currently the most widely used active ingredient in chemical combinations aimed at controlling target spot. Given the reduction in pathogen sensitivity to the various active ingredients registered for target spot control, it becomes necessary to seek effective alternatives for disease management.

Therefore, the objective of this study was to evaluate the effects of fungicide applications based

on prothioconazole, tebuconazole, fluxapyroxad, and pyraclostrobin on agronomic performance and disease control in cotton crops.

2 Material and Methods

The experiment was conducted in an experimental field located in the municipality of Diamantino, Mato Grosso, Brazil, at latitude 14°10'58" S and longitude 57°33'08" W, at an average altitude of 634 m. The regional climate is classified as humid megathermal tropical (Aw) according to the Köppen classification (Rocha *et al.*, 2018). The soil in the experimental area was corrected to achieve a base saturation of 60%.

Subsequently, based on the soil analysis results, 241 kg ha⁻¹ of the 09–40–00 fertilizer formulation was applied on the planting day. The cotton cultivar DP1949B3RF, which is susceptible to target spot and contains Bollgard 3 RRFlex technology, was used. After crop establishment, topdressing fertilization was carried out by broadcast application of 150 kg ha⁻¹ of KCl (Embrapa, 2014).

The experimental design was a randomized complete block design with eight treatments and four replications. Each experimental plot measured 5 m in length and 3 m in width, with 0.90 m row spacing and a seeding density of 10 seeds per meter, resulting in a total area of 15 m² per plot (Galbieri *et al.*, 2023). The experimental treatments, including active ingredient, concentration, commercial product dose, and application timing, are described in Table 1.

Table 1 - Treatments used in the fungicide trial, active ingredient, concentration, commercial product dose, and time of application

Treatments	Active Ingredient	Concentration	PC dose (L ha ⁻¹)	Application Timing ¹
T1 - Control	-	-	-	-
T2	Prothioconazole + Tebuconazole	1-300 g Kg ⁻¹	0.60	ABC ²
T3	Prothioconazole + Tebuconazole	1-300 g Kg ⁻¹	0.70	ABC
T4	Prothioconazole + Tebuconazole	1-300 g Kg ⁻¹	0.80	ABC
T5	Prothioconazole + Tebuconazole	1-300 g Kg ⁻¹	0.90	ABC
T6	Prothioconazole + Tebuconazole	1-300 g Kg ⁻¹	1.00	ABC
T7	Prothioconazole + Tebuconazole	1-300 g Kg ⁻¹	1.10	ABC
T8	Fluxapyroxad + Pyraclostrobin	167 + 333 g L ⁻¹	0.25*	ABC

Application timing: (A) represents the 1st application; (B) the 2nd application; and (C) the 3rd application. The 1st application (A) was performed on April 4, 2024, while the 2nd (B) and 3rd (C) applications were carried out at 14-day intervals. Assist (0.5%) was added.

Source: research data.

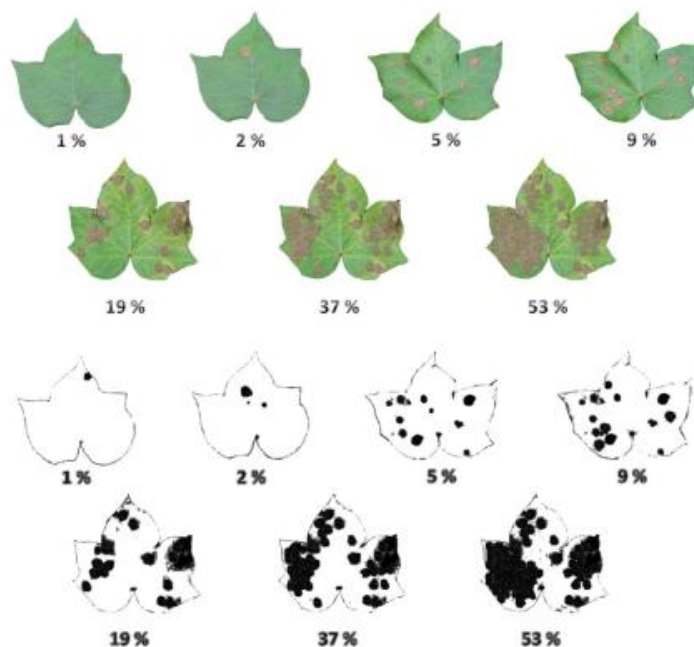
Foliar applications of the experimental treatments were divided into three applications per treatment, carried out using a CO₂-pressurized backpack sprayer equipped with a lateral boom 3 m in width, fitted with six flat-fan spray nozzles (model 110 015) spaced 50 cm apart, and calibrated at a

pressure of 2.5 bar to deliver an application rate of 150 L ha⁻¹. Applications were performed with the spray boom maintained at a height of 50 cm above the crop canopy in order to ensure uniform coverage (Cia *et al.*, 2020).

Six phytotoxicity assessments were conducted, prioritizing the two central rows, using a rating scale ranging from 1 (no visible phytotoxicity symptoms) to 9 (plant death), according to the EWRC methodology (1964). The first and second assessments were performed at 7 and 14 DAA (days after application A), the third and fourth at 7 and 14 DAB (days after application B), and finally the fifth and sixth assessments at 7 and 14 DAC (days after application C) (EWRC, 1964).

Prior to the first application, at 0 DAA (pre-application), the incidence of target spot on leaves was evaluated per plot in the experiment. Disease severity assessments were carried out at 7-day intervals after each application, prioritizing the two central rows. For application A, evaluations were conducted at 7 and 14 DAA; for application B, at 7 and 14 DAB; and, for application C, three evaluations were performed at 7, 14, and 21 DAC. Following the scale proposed by Fantin *et al.* (2018), the percentage of disease severity on leaves was estimated for each plot, as illustrated in Figure 1.

Figure 1 - Diagrammatic scale for the evaluation of target spot severity in cotton



Source: Fantin *et al.* (2018).

Based on disease severity, the area under the disease progress curve (AUDPC) was calculated at 21 DAC (Fantin, 2015).

$$AACPD = i \sum_{n=1}^{n-1} [(x_i + x_{i+1})] / 2 (t_{i+1} - t_i)$$

Where:

n is the total number of observations;

x_i is the disease severity (score in %) at the i th observation;

x_{i+1} is the disease severity at the $(i + 1)$ th evaluation;

t_{i+1} is the time of the $(i + 1)$ th evaluation;

t_i is the time (days) at the i th observation.

Following the methodology proposed by Godoy, Koga and Canteri (2006), the percentage of defoliation and the green leaf area were estimated in the plots based on visual ratings in the two central rows of each plot at 21 DAC.

At the end of the crop cycle, yield per plot was measured by harvesting the two central rows (discarding 1 m at each end), totaling approximately 3.6 m² per plot. Yield was converted to t ha⁻¹, and the relative increase (RI) in comparison with the untreated control was calculated (Lopes *et al.*, 2017).

Table 2 presents the crop growth stages at the different evaluation times, according to the BBCH phenological scale (Meier, 2018).

Table 2 - Mean crop growth stage at different evaluation times according to the BBCH phenological scale

Date	Application timing	Evaluation	BBCH Scale ⁴
04/04/2024	0 DAA ¹	Preliminary evaluation	31. 10% vegetation cover in the interrows.
11/04/2024	7 DAA	Efficiency and Phytotoxicity	32. 20% vegetation cover in the interrows;
18/04/2024	14 DAA	Efficiency and Phytotoxicity	36. 60% vegetation cover in the interrows;
25/04/2024	7 DAB ²	Efficiency and Phytotoxicity	39. Canopy closure;
02/05/2024	14 DAB	Efficiency and Phytotoxicity	69. End of flowering;
09/05/2024	7 DAC ³	Efficiency and Phytotoxicity	72. 20% of bolls at final size;
16/05/2024	14 DAC	Efficiency and Phytotoxicity	74. 40% of bolls at final size;
23/05/2024	21 DAC	Efficiency	76. 60% of bolls at final size;
06/08/2024	96 DAC	Harvest	99. Harvested product (bolls and seeds).

¹DAA – days after application A; ²DAB – days after application B; ³DAC – days after application C; ⁴BBCH – plant growth stage according to the BBCH scale.

Source: research data.

The obtained data were subjected to analysis of variance (ANOVA), and means were compared using Tukey's test at the 5% probability level. Treatment efficiency was estimated using the Abbott formula when necessary, with the aid of the SCOUT software (Engel *et al.*, 2018).

$$E (\%) = [(T - F) / T] \times 100$$

where:

T = percentage of disease severity in the untreated control;

F = percentage of disease severity in the fungicide-treated plots.

3 Results and Discussion

Table 3 presents the percentage of phytotoxicity at the different application and evaluation times. Despite the stress caused by irregular rainfall distribution during the 2023/2024 growing season, no phytotoxicity was observed at the tested doses of prothioconazole + tebuconazole (0.6 to 1.1 L ha⁻¹), nor in the standard treatment with fluxapyroxad + pyraclostrobin, across all evaluated periods. This also indicates that applications were carried out under conditions of lower plant stress and milder temperatures, since products based on prothioconazole and tebuconazole exhibit rapid absorption and slower vascular translocation rates. As a result, they may accumulate on the adaxial leaf surface, potentially causing leaf burn, especially when applications are performed under high temperatures (Goulart, 2022). Therefore, the cotton crop, cultivar DP1949B3RF, was selective to the evaluated products.

Table 3 - Percentage of phytotoxicity at different evaluation times

Treatments	Commercial product dose (L ha ⁻¹)	Application timing	7 DAA ₁		14 DAA ¹		7 DAB ²		14 DAB ²		7 DAC ³		14 DAC ³	
			%											
T1 - Control	-	-	0	a	0	a	0	a	0	a	0	A	0	A
T2 - Prothioconazole + Tebuconazole	0.60	ABC ⁴	0	a	0	a	0	a	0	a	0	A	0	A
T3 - Prothioconazole + Tebuconazole	0.70	ABC	0	a	0	a	0	a	0	a	0	A	0	A
T4 - Prothioconazole + Tebuconazole	0.80	ABC	0	a	0	a	0	a	0	a	0	A	0	A
T5 - Prothioconazole + Tebuconazole	0.90	ABC	0	a	0	a	0	a	0	a	0	A	0	A
T6 - Prothioconazole + Tebuconazole	1.00	ABC	0	a	0	a	0	a	0	a	0	A	0	A
T7 - Prothioconazole + Tebuconazole	1.10	ABC	0	a	0	a	0	a	0	A	0	A	0	A
T8 - Fluxapyroxad + Pyraclostrobin	0.25*	ABC	0	a	0	a	0	a	0	A	0	A	0	A

¹DAA – days after application A; ²DAB – days after application B; ³DAC – days after application C. The first application (A) was performed on April 4, 2024, and the second (B) and third (C) applications were carried out at 14-day intervals. ⁴Application timing: (A) corresponds to the 1st application; (B) to the 2nd application; and (C) to the 3rd application. *Assist (0.5%) was added. **Means followed by the same letter in the columns do not differ significantly according to Tukey's test at 5% probability.

Source: research data.

According to Godoy *et al.* (2020), understanding the cultivar's reaction to target spot is the first step in defining a fungicide management program, since many cultivars exhibit good tolerance or resistance to this disease and therefore do not require chemical control. For cultivars that do require control, the selection of appropriate fungicides is essential, as not all products show satisfactory

efficacy.

According to Godoy *et al.* (2024), during the 2023/2024 growing season, rainfall in the Mato Grosso Cerrado region occurred irregularly, and recorded temperatures were above normal, which favored the occurrence of phytotoxicity in soybean crops, characterized mainly by interveinal necrosis symptoms. These effects were primarily associated with products based on prothioconazole and tebuconazole. The highest percentages of phytotoxicity were observed in treatments containing metominostrobin + tebuconazole + chlorothalonil, pyraclostrobin + difenoconazole + prothioconazole, and bixafen + prothioconazole + trifloxystrobin, with mean phytotoxicity levels exceeding 8%.

Table 4 presents disease severity and percentage of control at the different evaluation times. No disease incidence was observed in the pre-application assessment, with infestation beginning from 7 DAB onward. From 14 DAB, all fungicide-treated plots reduced disease pressure and differed statistically from the untreated control in all evaluations, except for the 0.6 L ha⁻¹ dose. At 21 DAC, a substantial increase in target spot severity was observed in the untreated control, exceeding 42.46%. Under these conditions, the tested doses (0.6 to 1.0 L ha⁻¹) were effective, providing disease control ranging from 44.12% to 68.24%, and were statistically similar to the standard treatment (T8 – 0.25 L ha⁻¹), which achieved 58.82% control.

Table 4 - Disease severity by treatment (SEV) and percentage of control (Efficiency - %E) at different evaluation times

Treatment	Dose	Application	7 DAB		14 DAB		7 DAC		14 DAC		21 DAC	
			SEV	%E	SEV	%E	SEV	%E	SEV	%E	SEV	%E
T1	-	-	1.91 a	0.0	16.0 a	0.00	19.5 a	0.00	28.18 a	0.0	42.46 a	0.00
T2	0.60	ABC ²	1.21 ab	37.5	12.7 ab	21.54	15.6 b	19.23	22.54 b	19.5	23.58 b	44.12
T3	0.70	ABC	0.68 b	62.5	10.9 b	32.31	12.0 c	38.46	19.48 bc	31.0	20.00 bc	52.94
T4	0.80	ABC	0.68 b	62.5	10.4 b	35.38	11.5 c	41.03	18.97 bc	32.7	20.00 bc	52.94
T5	0.90	ABC	0.68 b	62.5	10.5 b	35.38	11.0 c	43.59	16.44 cd	41.6	17.41 cd	58.82
T6	1.00	ABC	0.68 b	62.5	11.5 b	29.23	11.5 c	41.03	13.42 d	52.2	13.46 d	68.24
T7	1.10	ABC	0.68 b	62.5	9.91 b	38.46	9.9 c	48.72	14.19 d	49.6	16.18 cd	61.76
T8	0.25*	ABC	0.87 b	50.0	9.91 b	38.46	12.1 c	37.18	16.44 cd	41.6	17.41 cd	58.82
DMS**			0.955	-	2.57	-	2.217	-	2.431	-	3.407	-
CV (%)***			0.47	-	0.60	-	4.64	-	3.58	-	6.37	-

¹ DAS, DAB, and DAC – days after application A, B, and C. ² The first application (A) was performed on April 4, 2024, and the second (B) and third (C) applications were carried out at 14-day intervals. ³ Means followed by the same letter in the columns do not differ significantly according to Tukey's test at 5% probability. * Assist (0.5%) was added. **DMS: Minimum significant difference; ***CV: Coefficient of variation. Treatments: T1 – Control; T2 – Prothioconazole + Tebuconazole; T3 – Prothioconazole + Tebuconazole; T4 – Prothioconazole + Tebuconazole; T5 – Prothioconazole + Tebuconazole; T6 – Prothioconazole + Tebuconazole; T7 – Prothioconazole +

Tebuconazole; T8 – Fluxapyroxad + Pyraclostrobin;
Source: Prepared by the authors (2025).

According to studies conducted in soybean by the FRAC (2023), data up to the 2021/22 growing season demonstrated that DMIs (prothioconazole and tebuconazole) showed similar effective control during this period, highlighting their efficacy in reducing EC_{50} values since the beginning of monitoring. However, Godoy *et al.* (2023) reported a progressive decline in the average efficacy of products formulated in mixtures associated with prothioconazole, which is currently the most widely used active ingredient in combinations and mixtures aimed at controlling target spot.

Godoy *et al.* (2023) obtained significant results for the prothioconazole + tebuconazole treatment, reducing disease severity by 17.9% and achieving approximately 58% control compared with the untreated control, yielding values similar to those observed in the present study. Furthermore, based on network trial data reported by Molina *et al.* (2019) evaluating fungicide efficacy, the best performances were observed in treatments containing the active ingredients fluxapyroxad + pyraclostrobin (76.2%) and epoxiconazole + fluxapyroxad + pyraclostrobin (75.7%), whereas the prothioconazole + trifloxystrobin treatment showed intermediate control efficiency (66.5%).

According to FRAC (2021), the average efficacy of the active ingredients fluxapyroxad + pyraclostrobin was 67%, based on trials conducted in different regions of Brazil from 2012 to 2018. Based on research results reported by Godoy *et al.* (2024), the mixture containing methyl tetraprole + prothioconazole and mancozeb resulted in the lowest disease severity (8.7%) and the highest target spot control performance, reaching 74%, whereas the mixture containing chlorothalonil + tebuconazole showed the lowest performance, with 51% control.

The results obtained in this study corroborate the findings reported by Godoy *et al.* (2016a, 2023, 2024) and by Molina *et al.* (2019) in other regions of Brazil, demonstrating the efficiency of the evaluated products for target spot control.

The percentage of defoliation and green leaf area (%), evaluated at 21 DAC, are presented in Table 5. For defoliation assessment, all tested doses and the standard treatment resulted in lower defoliation percentages, ranging from 12.5% to 21.25%, whereas the untreated control exhibited 30% defoliation due to the higher disease severity observed in this treatment. Doses between 0.8 and 1.1 L ha⁻¹ stood out in defoliation evaluation, showing the same statistical level as treatment 8, with reductions in defoliation relative to the untreated control ranging from 41.7% to 58.3%. For green leaf area evaluation, fungicide application resulted in the highest values, with emphasis on doses between 0.8 and 1.1 L ha⁻¹, which did not differ statistically from each other.

Table 5 - Defoliation percentage (%), defoliation reduction relative to the control, and green leaf area (%) at 21 DAC

Treatments	Commercial Product Dose (L ha ⁻¹)	Defoliation %	Defoliation Reduction %	Green Leaf Area %
T1 - Control	-	30.00 c	0.0	70.00 c
T2 - Prothioconazole + Tebuconazole	0.60	20.00 b	33.3	80.00 b
T3 - Prothioconazole + Tebuconazole	0.70	21.25 b	29.2	78.75 b
T4 - Prothioconazole + Tebuconazole	0.80	17.50 ab	41.7	82.50 ab
T5 - Prothioconazole + Tebuconazole	0.90	15.00 a	50.0	85.00 a
T6 - Prothioconazole + Tebuconazole	1.00	12.50 a	58.3	87.50 a
T7 - Prothioconazole + Tebuconazole	1.10	12.50 a	58.3	87.50 a
T8 - Fluxapyroxad + Pyraclostrobin	0.25*	13.75 a	54.2	86.25 a
DMS**	-	3.971	-	3.971
CV (%)***	-	15.16	-	3.29

¹ Means followed by the same letter in the columns do not differ significantly according to Tukey's test at 5% probability.

* Assist (0.5%) was added. **DMS: Minimum significant difference; ***CV: Coefficient of variation.

Source: research data.

According to Andrade and Andrade (2002), the occurrence of foliar diseases leads to a reduction in plant photosynthetic activity, caused by premature defoliation resulting from the destruction of leaf tissues. Molina *et al.* (2019) report that cultivars susceptible to the disease may experience yield losses of up to 40%, directly associated with defoliation.

In this context, Parciannello *et al.* (2004) describe that when defoliation occurs, plants may be induced to modify their developmental processes, exhibiting tolerance and compensating for leaf loss.

Several studies conducted in Brazil have reported the efficiency of fungicides in controlling target spot. Ribeiro *et al.* (2017), in a study evaluating chemical control efficiency of soybean target spot in the Cerrado, reported a 22.78% reduction in defoliation for the fluxapyroxad + pyraclostrobin treatment compared with the untreated control. In a similar study, Belufi *et al.* (2015) showed that all fungicide treatments differed statistically from the untreated control, highlighting reductions of 27% for the fluxapyroxad + pyraclostrobin treatment and 29% for the treatment containing prothioconazole + trifloxystrobin. Goulart (2022), in a study on the efficiency of triazoles in disease control, identified variation among treatments in defoliation control, ranging from 15% (prothioconazole + trifloxystrobin) to 66.3% (tebuconazole). The treatments prothioconazole + trifloxystrobin and prothioconazole alone showed the best results for defoliation control, with reductions of 84.5% and 68.6%, respectively, compared with the untreated control.

The data presented corroborate the efficiency and validate the results obtained in this study for controlling defoliation caused by *Corynespora cassiicola* in cotton crops.

Table 6 presents the area under the disease progress curve (AUDPC) for target spot (*Corynespora cassiicola*) in cotton. For the AUDPC evaluation, all fungicide treatments resulted in disease reduction, with particular emphasis on treatments 6 and 7, which showed the highest control

efficiency, reaching 49.57% and 50.57%, respectively. Treatments with doses ranging from 0.7 to 0.9 L ha⁻¹ of prothioconazole + tebuconazole were effective, providing disease control between 38.97% and 45.56%, and were statistically similar to treatment 8 (fluxapyroxad + pyraclostrobin), which achieved 44.41% control. These treatments differed significantly from the untreated control and from treatment 2 (Table 6 and Figure 2).

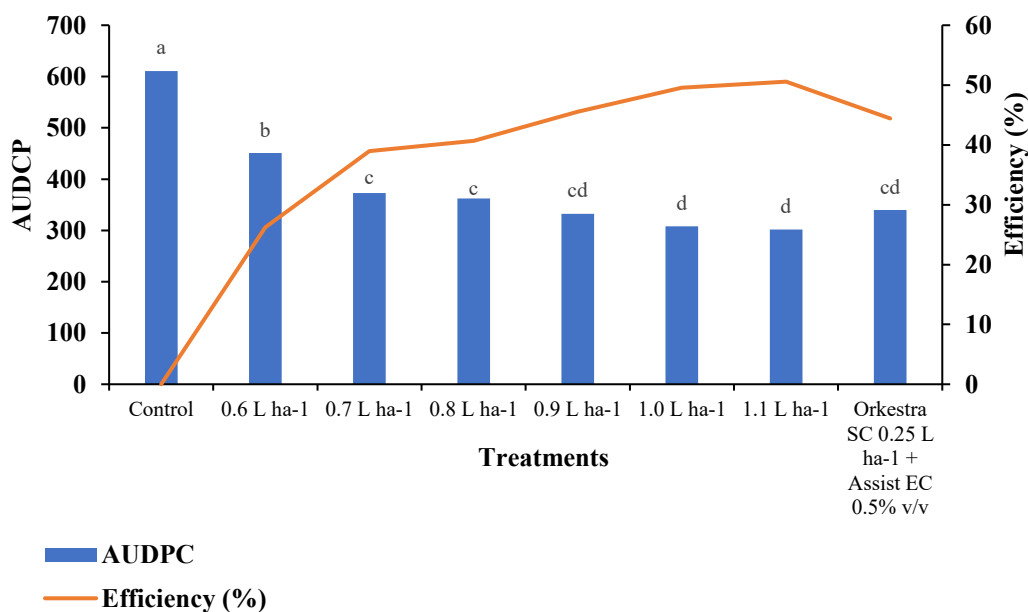
Table 6 - Area under the disease progress curve (AUDPC) of target spot (*Corynespora cassiicola*) in cotton.”

Treatments	Commercial Product Dose	AUDPC	Efficiency
	(L ha ⁻¹)		%
T1 - Control	-	610.75 a	0.00
T2 - Prothioconazole + Tebuconazole	0.60	450.63 b	26.22
T3 - Prothioconazole + Tebuconazole	0.70	372.75 c	38.97
T4 - Prothioconazole + Tebuconazole	0.80	362.25 c	40.69
T5 - Prothioconazole + Tebuconazole	0.90	332.50 cd	45.56
T6 - Prothioconazole + Tebuconazole	1.00	308.00 d	49.57
T7 - Prothioconazole + Tebuconazole	1.10	301.88 d	50.57
T8 - Fluxapyroxad + Pyraclostrobin	0.25*	339.50 cd	44.41
DMS**	-	6.99	-
CV (%)***	-	39.563	-

¹ Means followed by the same letter in the columns do not differ significantly according to Tukey’s test at 5% probability. *Assist (0.5%) was added. **DMS: Minimum significant difference; ***CV: Coefficient of variation.

Source: Prepared by the authors (2025).

Figure 2 - Area under the disease progress curve (AUDPC) of target spot (*Corynespora cassiicola*) in cotton.



¹ Means followed by the same letter in the columns do not differ significantly according to Tukey’s test at 5% probability. DMS: Minimum significant difference : 39.563; CV: Coefficient of variation: 6.99.

Source: research data.

Several authors have reported, in similar studies, the control efficiency of fungicide treatments compared with the untreated control. Belufi *et al.* (2015) described that all treatments combining one application of fluxapyroxad + pyraclostrobin followed by two sequential applications of prothioconazole achieved significant results in target spot control, with an AUDPC reduction of 90.75%, highlighting the effectiveness of this combination of active ingredients compared with the untreated control and outperforming the other treatments. According to results reported by Amthauer (2015), the fluxapyroxad + pyraclostrobin treatment showed the highest level of control, reaching 72%. Molina *et al.* (2019) reported that all treatments containing prothioconazole achieved control efficiency above 70%.

In the years prior to 2019, fungicides based on prothioconazole proved to be highly effective in controlling *C. cassiicola*. However, according to FRAC (2024), monitoring of target spot in cotton crops in Brazil during the 2024 season indicated a sensitive scenario for *C. cassiicola* to the DMI group, similar to that observed in the 2023 monitoring, with a reduction in control efficiency for this group.

When compared with the results reported by Molina *et al.* (2019) and Godoy *et al.* (2023), a decline in control efficiency is evident. Furthermore, according to Sacon *et al.* (2024), active ingredients such as carboxamides and strobilurins (fluxapyroxad and pyraclostrobin, respectively) have also experienced a loss of efficiency in the control of fungal diseases in cotton.

The results obtained in the present study corroborate the findings reported by Molina *et al.* (2019), Godoy *et al.* (2023), and FRAC (2024), which indicate a gradual reduction in the control efficiency of *C. cassiicola* in recent years for the DMI group, as well as the findings of Sacon *et al.* (2024) for carboxamides. Nevertheless, despite this gradual decline in efficiency, the evaluated products, when applied at appropriate doses, still demonstrated reasonable control efficiency for target spot AUDPC when compared with the untreated control.

Table 7 presents the evaluation of yield and relative increase (RI). Based on the obtained data, a significant difference among treatments was observed for the yield variable, with emphasis on treatment 6 (prothioconazole + tebuconazole) at the dose of 1.0 L ha⁻¹, which resulted in the highest relative yield increase, reaching approximately 22.01%. Treatment 2 (prothioconazole + tebuconazole) at the dose of 0.6 L ha⁻¹ showed the lowest performance among fungicide-treated plots, with a 1.49% increase that did not differ statistically from the untreated control. However, no significant differences were observed among treatments T2 to T8, except for treatment 6. Treatments T3 to T7 showed yield increases compared with the untreated control, ranging from 7.3% to 22.01%, and were statistically similar to treatment 8, which achieved a 9.44% increase (Table 7).

Table 7 - Cotton yield evaluation and relative increase (RI) of the experimental treatments

Active ingredient	Commercial product dose	Application timing ¹	Cotton yield (t ha ⁻¹)	RI (%)
	(L ha ⁻¹)			
T1 - Control	-	-	4.06 c	0.00
T2 - Prothioconazole + Tebuconazole	0.60	ABC	4.12 bc	1.49
T3 - Prothioconazole + Tebuconazole	0.70	ABC	4.39 ab	7.99
T4 - Prothioconazole + Tebuconazole	0.80	ABC	4.36 ab	7.30
T5 - Prothioconazole + Tebuconazole	0.90	ABC	4.55 ab	11.92
T6 - Prothioconazole + Tebuconazole	1.00	ABC	4.95 a	22.01
T7 - Prothioconazole + Tebuconazole	1.10	ABC	4.57 ab	12.43
T8 - Fluxapyroxad + Pyraclostrobin	0.25*	ABC	4.44 ab	9.44
DMS**	-	-	0.174	-
CV (%)***	-	-	7.40	-

¹Application timing; (A) corresponds to the 1st application; (B) corresponds to the 2nd application; (C) corresponds to the 3rd application. ²Means followed by the same letter do not differ significantly within columns, according to Tukey's test at 5% probability. *Assist (0.5%) was added; ** DMS: Minimum significant difference; ***CV: Coefficient of Variation.

Source: research data.

According to the results reported by Godoy *et al.* (2023), in studies evaluating fungicide efficiency for target spot control, the treatment prothioconazole + tebuconazole was highly effective for the yield variable, providing approximately a 12.3% increase in productivity compared to the untreated control. This result is similar to that observed in the present study, which showed yield increases ranging from 7.3% to 22.01% with the same active ingredients. These findings corroborate the observations of Godoy *et al.* (2024), who reported that all treatments containing prothioconazole in their composition achieved higher productivity levels compared to treatments with other active ingredients, highlighting the effectiveness of this active ingredient when combined with compounds from different chemical groups.

Ribeiro *et al.* (2017), in a study on target spot control in soybean, identified statistically significant differences for the treatment fluxapyroxad + pyraclostrobin (2,486 kg ha⁻¹), with an increase of 285 kg ha⁻¹ compared to the untreated control (2,201 kg ha⁻¹), corresponding to a relative yield increase of 13%. Similarly, according to Godoy *et al.* (2016b), the treatment fluxapyroxad + pyraclostrobin resulted in the highest yield (3,387 kg ha⁻¹), and when compared to the untreated control (2,844 kg ha⁻¹), it showed a relative increase of 19.1%.

These results are consistent with the data observed in the present study, which demonstrated productivity gains compared to the untreated control and to treatments using lower fungicide doses, thereby validating the effectiveness of the evaluated products in increasing yield.

In this study, a cultivar susceptible to target spot was used. Godoy *et al.* (2024) emphasize that integrated control strategies should be adopted to minimize disease progression, highlighting the importance of using cultivars with resistant or tolerant technologies, seed treatment, periodic monitoring of the pathogen, and crop rotation, especially with grasses. Understanding the cultivar's

response to the disease is essential for adopting more efficient chemical control strategies using fungicides appropriate for each cultivar, since not all control programs provide satisfactory efficiency.

4 Conclusion

All treatments reduced disease progression; however, the treatments containing prothioconazole + tebuconazole at doses ranging from 1.0 to 1.1 L ha⁻¹ showed the best results compared to the untreated control in the evaluation of the area under the disease progress curve, with control efficiencies of 49.57% and 50.57%, respectively. All treatments resulted in increased productivity; however, the treatment prothioconazole + tebuconazole at the dose of 1.0 L ha⁻¹ achieved the highest yield, reaching 4.95 t ha⁻¹, with a relative increase of 22.01%. Therefore, it can be concluded that the treatment containing prothioconazole + tebuconazole at the dose of 1.0 L ha⁻¹ showed the best overall performance among the evaluated treatments, standing out in relation to the assessed variables.

References

- ABRAPA. Associação Brasileira dos Produtores de Algodão. 2024. *Relatório safra: junho de 2024*. Disponível em: <https://abrapa.com.br/wp-content/uploads/2024/06/Relatorio-de-Safra-Jun-2024.pdf>. Acesso em: 15 ago. 2025.
- ALCANTARA, I. *et al.* *Produtividade do algodão no Brasil: uma análise da mudança estrutural*. Brasília: IPEA, 2021.
- AMORIM, L. *et al.* *Manual de Fitopatologia*. Piracicaba: Agronômica Ceres, 2011.
- AMPA. Associação Matogrossense dos Produtores de Algodão. *História do algodão*. Disponível em: <https://ampa.com.br/historia-do-algodao/>. Acesso em: 4 set. 2025.
- AMTHAUER, J.A.S. *Controle químico de Corynespora cassiicola em cultivares de soja no município de Rio Verde-Goiás*. 2015. Dissertação (Mestrado em Produção Vegetal) - Universidade de Rio Verde – UNIRV, Rio Verde, 2015.
- ANDRADE, P.J.M.; ANDRADE, D.F.A. *Ferrugem Asiática: uma ameaça à sojicultura brasileira*. Brasília: Embrapa Agropecuária Oeste, 2002, 12 p. (Circular técnica, 11).
- BÉLOT, J.L. *et al.* Riscos e oportunidades: o bicudo-do-algodoeiro. In: PICCOLI, G. V.; DALCIN, E.; LOPES, M.A. *Desafios do Cerrado: como sustentar a expansão da produção com produtividade e competitividade*. Cuiabá: AMPA, 2016, p. 77-118.
- BELUFI, L.; KEMPIM, F.; PASQUALLI, R. *Avaliação da eficiência de fungicidas aplicados no vegetativo para o controle de manchas alvo (Corynespora cassiicola) na cultura de soja no Mato Grosso*. Lucas do Rio Verde: Fundação Rio Verde, 2015. 6 p. (Boletim técnico, 23).
- BRENT, J.K.; HOLLOMON, D.K. *Fungicide resistance in crop pathogens: how can it be managed*. Bruxelas: FRAC, 2007.

CANTERI, M.G. *et al.* SASM-AGRI: Sistema para análise e separação de médias em experimentos agrícolas pelos métodos Scott-Knott, Tukey e Duncan. *Rev. Bras. Agro Comp.*, v.1, n.2, p.18-24, 2001.

CERUTTI, F.C. *et al.* Manejo químico da ferrugem asiática da soja. *Rev. Ibe. Amer. Hum. Ciênc. Educação*, v.7, n.11, p.244-256, 2021.

CIA, E. *et al.* *Reação de cultivares de algodoeiro a doenças e nematoides, safra 2019/20*. Primavera do Leste: IMA, 2020.

CONAB. Companhia Nacional de Abastecimento. *Acompanhamento da Safra Brasileira de Grãos: safra 2023/24 décimo levantamento*. v. 11, n. 10, p. 26-36, 2024.

ELLIS, M.B. *et al.* Some species of *Corynespora*. *Mycol. Paper.* v. 9, n. 65, p.1-15, 1957.

EMBRAPA. *Adubação do Algodoeiro no Ambiente de Cerrado*. Campina Grande: EMBRAPA, 2014.

ENGEL, E. *et al.* Eficiência econômica de inseticidas sobre *Euschistus heros* na cultura da soja. *Rev. Interd. Ens. Pesq. Extensão*, v. 6, n. 1, p. 350-357, 2018.

EWRC. European Weed Research Council. Report of the 3rd and 4rd meetings of EWRC. Committee of methods in weed research. *Weed Res.*, v.4, n.1, p.87-88, 1964.

FANTIN, L.H. *et al.* Development and validation of diagrammatic scale to assess target spot severity in cotton. *Austral. Plant Pathol.*, v. 47, p. 491-497, 2018.

FANTIN, L.H. Escala diagramática para avaliação de severidade de mancha alvo (*Corynespora cassiicola*) em algodão. Londrina: UEL, 2015.

FRAC. Fungicide Resistance Action Committee. *Informação preliminar sobre carboxamidas para mancha-alvo*. Holambra: FRAC, 2021.

FRAC. Fungicide Resistance Action Committee. Summary of annual Sensitivity Monitoring. Holambra: FRAC, 2023.

FRAC. Fungicide Resistance Action Committee. *Protocol of the discussions and recommendations of the SBI working group of the Fungicide Resistance Action Committee*. Frankfurt: FRAC, 2024.

GALBIERI, R. *et al.* *Corynespora* leaf blight of cotton in Brazil and its management. *Amer. Plant Sciences*, v. 5, n. 26, p. 3805-3811, 2014.

GALBIERI, R. *et al.* *Reação de cultivares de algodoeiro a doenças e nematoides: safra 2020/21*. Primavera do Leste: IMA, 2021.

GALBIERI, R. *et al.* *Reação de cultivares de algodoeiro a doenças e nematoides: safra 2022/23*. Primavera do Leste: IMA, 2023.

GODOY, C. V.; KOGA, L. J.; CANTERI, M. G. Diagrammatic scale for assessment of soybean rust severity. *Fitop. Brasileira*, v. 31, n. 1, p. 63-68. 2006.

GODOY, C. V. *et al.* Doenças da soja. In: AMORIM, L. *et al.* *Manual de fitopatologia: doenças das* Ensaios e Ciência, v.1, n.2, p.59-75, 2026.

plantas cultivadas. Ouro Fino: Agrônômica Ceres, 2016a. p. 657-675.

GODOY, C.V. *et al.* Eficiência de fungicidas para o controle de mancha-alvo, *Corynespora cassiicola*, na cultura da soja, na safra 2015/2016: resultados sumarizados dos ensaios cooperativos. Londrina: Embrapa Soja, 2016b.

GODOY, C.V. *et al.* Eficiência de fungicidas para o controle de mancha-alvo, *Corynespora cassiicola*, na cultura da soja, na safra 2022/2023: resultados sumarizados dos ensaios cooperativos. Londrina: Embrapa Soja, 2023.

GODOY, C.V. *et al.* Eficiência de fungicidas para o controle de mancha-alvo, *Corynespora cassiicola*, na cultura da soja, na safra 2023/2024: resultados sumarizados dos ensaios cooperativos. Londrina: Embrapa Soja, 2024.

GOULART, M.C.N. *Triazóis isolados no manejo de ferrugem asiática da soja*. 2022. Dissertação (Mestrado em Bioenergia e Grãos) - Instituto Federal de Educação, Ciência e Tecnologia Goiano – Campus Rio Verde. Rio Verde - GO. 2022.

HENNING, A.A. *et al.* Manual de identificação de doenças de soja. Londrina: Embrapa Soja, 2010. 53 p. (Documentos, 256).

LOPES, L.O. *et al.* Efeito de fungicidas para o controle de *Ramularia areola* na cultura do algodoeiro. *Sum. Phytopathologica*, v.43, n.3, p.229-235, 2017.

MARQUES, A.L.R. *et al.* Eficiência de uso e resposta à aplicação de fósforo de cultivares de algodão em solo do Cerrado. *Ens. Ciênc.*, v.28, n.2, p.149-158, 2024. doi: <https://doi.org/10.17921/1415-6938.2024v28n2p149-158>

MEIER, U.E. *Growth stages of mono and dicotyledonous plants: BBCH monograph*. Quedlinbur: Julius Kühn-Institut Federal Research Centre for Cultivated Plants, 2018.

MELO, P.T.N.B.; BELLEN, H.M. Institutional dimension for sustainable development: the relationship of organic and conventional cotton farming with government. *Rev. Econ. Soc. Rural*, v.60, n.1, p.e224662, 2022. doi: 10.1590/1806- 9479.2021.224662

MEYER, M.C. *et al.* Eficiência de fungicidas para controle de mofo-branco (*Sclerotinia sclerotiorum*) em soja, na safra 2017/18: resultados sumarizados dos ensaios cooperativos. Londrina: Embrapa Soja, 2018. 6 p. (Circular técnica, 140).

MOLINA, J.P.E. *et al.* Meta analysis of fungicide efficacy on soybean target spot and cost-benefit assessment. *Plant Pathology*, v.68, n.1, p.94-106, 2019.

OLIVEIRA, R.R. *et al.* Chlamydospore formation by *Corynespora cassiicola*. *Trop. Plant Pathol.*, v.37, n.6, p.415-418, 2012.

PARCIANELLO, G. *et al.* Tolerância da soja ao desfolhamento afetada pela redução do espaçamento entre fileiras. *Ciênc. Rural*, v. 34, n.2, p.357-364, 2004.

QI, Y. *et al.* Morphological and molecular analysis of genetic variability within isolates of *Corynespora cassiicola* from different hosts. *Euro. J. Plant Pathol.*, v.130, n.1, p.83-95, 2011.

RIBEIRO, F.D.C. *et al.* Controle químico da mancha-alvo da soja (*Corynespora cassiicola*) no Ensaio e Ciência, v.1, n.2, p.59-75, 2026.

cerrado tocantinense - Brasil. *J. Bioen. Ciênc. Alim.*, v.4, n.1, p.26-36, 2017.

ROCHA, A.A. *et al.* Caracterização da variabilidade climática em Diamantino/MT - Brasil no período de 1987 a 2017. *Enciclop. Biosf.*, v.15, n.27, p.71-72, 2018.

SACON, D. *et al.* Surto de manchas foliares causado por *Corynespora cassiicola* na cultura do algodoeiro em Mato Grosso. *Rev. Cult. Gran. Culturas*, v.25, n.294, p.35-39, 2024.

VILELA, G.F. *et al.* Cerrado: agricultural production and areas designated for environmental preservation registered in the Brazilian rural environmental registry (Cadastro Ambiental Rural). *J. Env. Sci. Engin.*, v.9, n.3, p.87-107, 2020. doi: 10.17265/2162-5263/2020.03.001

WEI, C.T. Notes on *Corynespora*. *Mycol. Papers*. v. 30, n. 34, p. 1-10, 1950.