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Maximizando a qualidade dos grãos de milho: estratégias avançadas de controle químico de doenças foliares

Maximizing corn grain quality: advanced strategies for chemical control of leaf diseases

Maximización de la calidad del grano de maíz: estrategias avanzadas para el control químico de las enfermedades de las hojas

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Elvis Josefer Constantino
Mestrado em Agronomia
Instituição: Programa de Pós-Graduação em Agronomia da Universidade Federal de Mato Grosso (PPGA – UFMT)
Endereço: Cuiabá, Mato Grosso, Brasil
E-mail: elvisconstantino@yahoo.com.br

Lucas Rodrigues Versari
Graduado em Engenharia Agronômica
Instituição: Universidade Federal de Mato Grosso (UFMT)
Endereço: Cuiabá, Mato Grosso, Brasil
E-mail: lucasvr71@hotmail.com

Márcio Roggia Zanuzo
Doutor em Ciência e Tecnologia Agroindustrial
Instituição: Programa de Pós-Graduação em Agronomia da Universidade Federal de Mato Grosso (PPGA – UFMT)
Endereço: Cuiabá, Mato Grosso, Brasil
E-mail: marcio.zanuzo@ufmt.br

Dulândula Silva Miguel Wruck
Doutora em Fitopatologia
Instituição: Embrapa Agrossilvipastoril
Endereço: Cuiabá, Mato Grosso, Brasil
E-mail: dulandula.wruck@embrapa.br

Solange Maria Bonaldo
Doutor em Fitopatologia
Instituição: Programa de Pós-Graduação em Agronomia da Universidade Federal de Mato Grosso (PPGA – UFMT)
Endereço: Cuiabá, Mato Grosso, Brasil
E-mail: solange.bonaldo@ufmt.br

Carlos Guilherme Theodoro dos Santos
Graduado em Engenharia Agronômica
Instituição: Programa de Pós-Graduação em Agronomia da Universidade Federal de Mato Grosso (PPGA – UFMT)
Endereço: Cuiabá, Mato Grosso, Brasil
E-mail: carlosguith@gmail.com

João de Andrade Bonetti
Doutor em Ciências do Solo
Instituição: Departamento de Ciência Florestal, Solos e Ambientes da Universidade Estadual Paulista "Júlio de Mesquita Filho"
Endereço: Botucatu, São Paulo, Brasil
E-mail: joao.bonetti@unesp.br

RESUMO
A crescente incidência de doenças foliares tem impactado negativamente na qualidade e produtividade dos grãos de milho na segunda safra. Nesse contexto, este estudo teve como objetivo avaliar a eficácia de fungicidas no controle dessas doenças e seu efeito sobre a produtividade do milho. O experimento foi conduzido em blocos casualizados, com 16 tratamentos e quatro repetições, utilizando diferentes fungicidas dos grupos químicos dos triazóis, carboxamidas e estrobilurinas. As aplicações foram realizadas nos estágios de desenvolvimento V6 e pré-pendoamento do híbrido DKB 390 PRO3. Os fungicidas contendo ingredientes ativos pertencentes ao grupo químico carboxamidas foram mais eficientes no controle da mancha de diplodia (*Stenocarpella macrospora*) e de ferrugem polissora (*Puccinia polysora*). A associação de carboxamida, triazol e estrobilurina em suas formulações foram mais eficientes no controle de mancha foliar de Diplodia, resultando em maior integridade dos colmos. As doenças foliares avaliadas impactaram diretamente na qualidade de grãos e, entre as espécies de fungo, *S. macrospora* foi a de maior ocorrência nos grãos ardidos no presente trabalho. A produtividade de milho foi maior nos tratamentos com mistura T4 e T12-T16, com média de 8.787,6 kg ha^{-1}, superando a testemunha (7.500,0 kg ha^{-1}), sendo que o PMS não sofreu alteração. Esses resultados destacam a importância do manejo eficaz das doenças foliares para garantir a qualidade e a produtividade do milho em segunda safra.

Palavras-chave: *Fusarium* sp., *Puccinia polysora*, Fungicidas.

ABSTRACT
The increasing incidence of foliar diseases has negatively impacted the quality and productivity of corn grains in the second crop. In this context, this study aimed to evaluate the efficacy of fungicides in controlling these diseases and their effect on corn productivity. The experiment was conducted in randomized complete blocks with 16 treatments and four replications, using different fungicides from the chemical groups of triazoles, carboxamides, and strobilurins. Applications were made at the V6 and pre-tasseling stages of the DKB 390 PRO3 hybrid. Fungicides containing active ingredients belonging to the chemical group carboxamides were more efficient in the control of Diplodia leaf streak (*Stenocarpella macrospora*) and also of Southern corn rust (*Puccinia polysora*). The association of carboxamide, triazole and strobilurins were more efficient, resulting in the control of Diplodia leaf streak and, consequently, greater integrity of the stems. The evaluated foliar diseases had a direct impact on the quality of the grains and, among the fungus species, *S. macrospora* was the one with the highest occurrence in the burnt grains in the present study. Corn productivity was higher in treatments with the T4 and T12-T16 mixtures, averaging 8,787.6 kg ha^{-1}, surpassing the control (7,500.0 kg ha^{-1}), while the thousand kernel weight remained unchanged. These results highlight the importance of effective foliar disease management to ensure the quality and productivity of corn out of season.

Keywords: *Fusarium* sp., *Puccinia polysora*, Fungicides.

RESUMEN
La creciente incidencia de enfermedades foliares ha impactado negativamente la calidad y productividad de los granos de maíz en la segunda cosecha. En este contexto, este estudio tuvo como objetivo evaluar la efectividad de los fungicidas en el control de estas enfermedades y su efecto en la productividad del maíz. El experimento se realizó en bloques al azar, con 16 tratamientos y cuatro repeticiones, utilizando diferentes fungicidas de los grupos químicos de triazoles, carboxamidas y estrobilurinas. Las aplicaciones se realizaron en las etapas de desarrollo V6 y precurtido del híbrido DKB 390 PRO3. Los fungicidas que contienen ingredientes activos pertenecientes al grupo químico de las carboxamidas fueron más eficaces para controlar la mancha foliar por diplodia (*Stenocarpella macrospora*) y la roya por polisporas (*Puccinia polysora*). La combinación de carboxamida, triazol y estrobilurina en sus formulaciones fue más eficiente para controlar la mancha foliar por Diplodia, lo que resultó en una mayor integridad del tallo. Las enfermedades foliares evaluadas tuvieron un impacto directo en la calidad del grano y, entre las especies de hongos, *S. macrospora* fue la de mayor ocurrencia en los granos quemados en el presente estudio. La productividad del maíz fue mayor en los tratamientos con la mezcla T4 y T12-T16, con un promedio de 8.787,6 kg ha-1, superando al testigo (7.500,0 kg ha-1), y el PMS no varió. Estos resultados resaltan la importancia del manejo efectivo de las enfermedades foliares para garantizar la calidad y productividad del maíz en la segunda cosecha.

Palabras clave: *Fusarium* sp., *Puccinia polysora*, Fungicidas.

1 INTRODUCTION

The culture of corn (*Zea mays* L.) is of great importance within the production system, not only for its economic aspects but also as a component in the crop rotation system. This importance is due, among many factors, to genetic improvement, which has increased the yield potential, making the crop increasingly demanding in its management (Darós, 2015). Over the past few years, with the adoption of second-crop corn sowing following the soybean culture, there has been greater pressure from diseases in corn cultivation, possibly associated with the increase in areas cultivated with this cereal.

The extensive cultivation and climatic conditions in a tropical country like Brazil favor the occurrence of diseases that affect the crop. The increase in foliar diseases, associated with favorable climatic conditions and hybrid susceptibility, also leads to an increase in the incidence of grain and ear rots (Cota, 2013). Fungi are the main cause of the occurrence of moldy grains, and among them, fungi of the genera *Stenocarpella* spp. and *Fusarium* spp. stand out (Stefanello et al., 2012).

The presence of these pathogens in grains is a major concern due to their ability to produce toxic secondary metabolites, called mycotoxins, which pose a serious problem for human and animal health (Gromadzka et al., 2016). Even at low concentrations, mycotoxins can cause chronic diseases (Savi, 2020). One of the diseases that occur most frequently and severely in the Northern region of the Mato Grosso State is Diplodia leaf streak (*Stenocarpella macrospora*), (Earle) Sutton [Syn. *Diplodia macrospora* Earle in Bull.].

However, there is little information related to specific management strategies for this disease (Casa et al., 2010) due to its wide distribution throughout Brazil. In addition to Diplodia leaf streak, the fungus *S. macrospora* can cause stem rot, ear rot, and moldy grains (Contini et al., 2019). Losses related to moldy grains can be quantitative (lower weight grains) and qualitative (related to the nutritional quality of the grains). Currently, industries that use corn grains (*Zea mays* L.) as raw material for human and animal feed are concerned about the quality of the product and adopt a maximum tolerance of 6% for moldy grains in commercial corn batches (Senar, 2017; Gromadzka et al., 2016).

Southern rust (*Puccinia polysora* Underw.) is one of the most destructive diseases of corn, occurring in important production areas in Brazil (Pinho, 1999). Under favorable conditions for its occurrence, some genotypes tested in regional genotype evaluation trials had more than 75% leaf area affected by the disease (Dudienas et al., 2013). Southern rust is considered the most aggressive and destructive, causing economic damage of up to 65% (Costa et al., 2012). Genetic resistance has been one of the widely used control measures in the management of southern rust. However, the high genetic variability of the pathogen complicates the obtaining of resistant hybrids (COSTA et al., 2019).

In recent years, the use of fungicides has been adopted for the control of foliar diseases in corn, including southern rust (Cota et al., 2018). However, there are still few studies in the literature related to the effectiveness of fungicide use in the control of this disease (Costa et al., 2013). The objective of this study was to determine the effect of fungicides on the management of foliar diseases, incidence of moldy grains, fungi associated with moldy grains, and productivity in corn cultivation.

2 MATERIAL AND METHODS

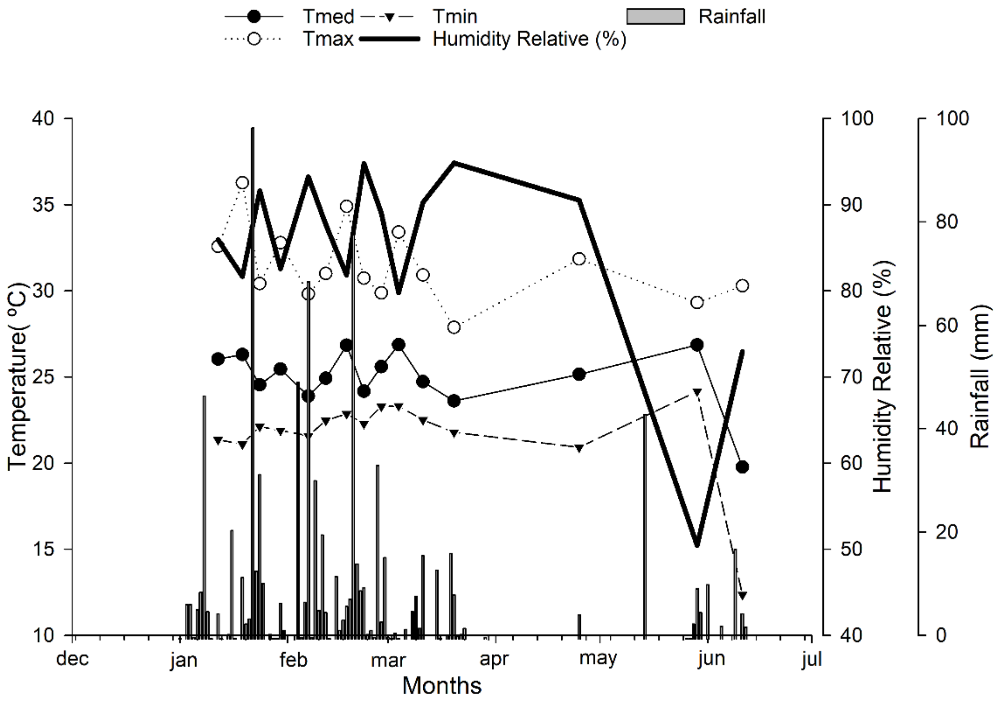
The field experiment was carried out during the 2019/2020 harvest, at the Experimental Station of EPR Consultoria e Pesquisa Agronômica, located in Sinop – MT (12°35’23” S and 55°51’31” W). The experimental design used was randomized blocks with 16 treatments (T1 to T16) and four replications.

Each plot consisted of six 12 m long rows spaced 0.45 m, with total area of 32.4 m2. The useful area was 18 m², consisting of the 4 central lines excluding border lines.

The soil in the experimental area is classified as dystrophic Red Oxisol (Santos et al., 2018), clayey texture (51.34% clay, 28.4% sand and 10.26% silt).4The soil in the 0-20 cm layer presented: pH in water = 5.7; V% 47.92%, CTC pH 7 10.8%; sum of bases of 4.83 Cmolc/dm³; organic matter of 8.3 and Al and H contents of 5.2 and 33.9 cmolc/dm³, respectively.

Climatic data for the 2019/2020 harvest were obtained from the meteorological station located at the EPR experimental station, Sinop – MT are presented in the Figure 1.

Figure 1. Temperature, Relative Humidity and Rainfall during experimental setup with fungicides to control leaves diseases in corn yield. Climates dates / EPR, Sorriso/MT, 2020.



Fonte: Autores

The DKB 390 PRO3 corn hybrid was sowed on February 22, 2020, with a population of 55,000 plants ha^{-1}. The hybrid used is recommended for the region and presents moderate tolerance to the pathogens *S. macrospora* and *P. polysora*.

Nutrients for plant growth were added by spread using 200 kg ha^{-1} of formulation 16-16-16 (NPK) and 300 kg ha^{-1} of formulation 20-00-20 (NPK) divided into two periods, 20 and 30 days after sowing.

Fungicides were applied twice times (2X), at the phenological stage of six developed leaves (V6) and at pre-bolting (VT) using the pressurized sprayer of CO_2, with a pressure of 2.6 bar and a spray volume of 140 L ha^{-1}. In the Table 1 is described the molecule fungicide and your respective concentration.

Table 1. Treatments of fungicides used in the control of foliar diseases in corn crops during the 2019/2020 season in Sorriso-MT

Trat.	Active Ingredient	g.i.a/ha
T1	Control	-------
T2	Trifloxystrobin + Ciproconazole	75 + 32
T3	Pyraclostrobin + Mefentrifluconazole	200 + 200
T4	Pyraclostrobin + Fluxapyroxad + Mefentrifluconazole	106.8 + 53.4 + 79,8
T5	Azoxystrobin + Tebuconazole	60 + 100
T6	Pyraclostrobin + Epoxiconazole	78 + 48
T7	Azoxystrobin + Ciproconazole	60 + 24
T8	Azoxystrobin + flutriafol	75 + 75
T9	Picoxystrobin + Ciproconazole	80 + 32
T10	Prothioconazole + Trifloxystrobin	70 + 60
T11	Difenoconazole + Ciproconazole	75 + 45
T12	Fluxapyroxad + Pyraclostrobin	50.1 + 99.9
T13	Bixafen + Prothioconazole + Trifloxystrobin	62.5 + 87.5 + 75
T14	Azoxystrobin + Benzovindiflupyr	60 + 30
T15	Picoxystrobin + Benzovindiflupyr	60 + 30
T16	Azoxystrobin + Difenoconazole + Chlorothalonil	80 + 1000

Fonte: Autores

The area used to carry the experiment has a history of corn cultivation for 7 years, and always with reports of disease incidence. The soybean (season) and corn cultivation system (out of season) has been used in succession, in a direct planting system and supplementary irrigation via central pivot.

The evaluation of the severity of rust (*P. polysora*) was carried out on the ear leaf of ten random plants in the useful plot, with the aid of Fantin's diagrammatic scale (1997), notes, 0.1; 0.3; 0.7; two; 5; 12; 27; 50 and more than 50% of the leaf area affected by the disease.

For the evaluation of Diplodia leaf streak (S. macrospora), grades from 1 to 9 were assigned, representing severities equal to 0; 1; 2.5; 5; 10; 25; 50; 75 and more than 75% respectively, with the help of the diagrammatic scale proposed by Agroceres (1993). The evaluation of Diplodia leaf streak was carried out in the two central rows, assigning an average severity score to each plot. Assessments were carried out at intervals of seven days, totaling 28 days. From the disease data, the Area Under the Disease Progress Curve" (AUDPC) was calculated, according to Campbell and Madden (1990).

Two central lines were manually harvested, disregarding 0.5 m from each end, in a total area of 9 m2. The mass of one thousand grains (g) were determined according to the Rules for Seed Analysis (RAS) (Brazil, 2009), and the grain yield (kg ha-1), both correcting the humidity to 13%.

The incidence of burned grains was carried out according to the procedure proposed by ordinance nº 11, of 04/12/96, Brazil (1996). The method consists of visual separation and determination of the percentage of grains with symptoms of discoloration on more than a quarter of their total surface, based on a sample of 250 g of grains per plot. The burned grains were weighed, and the data expressed as a percentage of the total weight of the sample.

From each plot, 2 kg of seeds were collected and sent for seed pathology analysis at the Phytosanitary/Phytopathology Laboratory of Embrapa Agrossilvipastoril, Sinop – MT and at the Bayer Laboratory, Uberlândia – MG.

To identify and determine the incidence of fungi in burned grains, 400 symptomatic grains were visually selected per treatment (Mário & Reis, 2001). Subsequently, the grains were superficially disinfected by immersing them in 2.5% sodium hypochlorite for three minutes, followed by two consecutive washes in sterilized distilled water. The disinfested grains were transferred to acrylic boxes, type gerbox®, containing three sheets of filter paper moistened with distilled and sterilized water. Twenty grains were distributed in each box and incubated at 25 ± 2 ºC, with a 12-hour photoperiod under fluorescent lights. After 15 days of incubation, pathogens with mycelial growth on the grains were identified using a stereoscopic microscope (80 x) and an optical microscope (400 x). The results were expressed as a percentage of grains infected (incidence) by each microorganism.

The data obtained were subjected to the Shapiro-Wilk normality test, with the data on the incidence of fungi in burned grains being transformed to $\sqrt{x}+1$. Subsequently, analysis of variance (ANAVA) was carried out, at a level of 5% probability using the F test. When significant, the variables were compared using the Schott-Knott test at 5% probability, with the help of the statistical program (SISVAR) (Ferreira, 2014).

3 RESULTS AND DISCUSSIONS

The main diseases that occurred in plants during the experiment were Diplodia leaf streak and Southern corn rust. The Diplodia leaf streak was predominant, probably due to the favorable environmental conditions and the susceptibility of the hybrid used (Table 2). In the present work, temperatures of 18°C to 28°C and relative humidity of 46% to 96.4% were recorded (Figure 1).

For Diplodia leaf streak, all fungicides were superior to the control in reducing leaf severity. The effectiveness of fungicides in controlling Diplodia leaf streak ranged from 46.2% to 92.6%. The fungicides that showed the greatest efficiency were pyraclostrobin + fluxapyroxad + Mefentrifluconazole (T4) and Bixafen + prothioconazole + trifloxystrobin (T13), both with values above 92% and did not differ from each other.

Then the treatments fluxapiroxad + pyraclostrobin, picoxystrobin + benzovindiflupyr, prothioconazole + trifloxystrobin and azoxystrobin + benzovindiflupyr, showed control between 82.20% and 86.06%. The treatments with the lowest control of Diplodia leaf streak were with the fungicides difenoconazole + cyproconazole and picoxystrobin + cyproconazole, with AUDPC values lower only than those of the control.

The two treatments with the greatest Diplodia leaf streak control (T4 and T13) have a triple mixture of triazole, carboxamide and strobilurin, which act on different biochemical processes of the fungus, such as: inhibition of demethylation (IDM), external quinone (IQe) and succinate dehydrogenase (ISDH) (Schmitz et al., 2014; Klosowski et al., 2016; Simões et al., 2018). This mixture increases the period of protection and spectrum of action of the product against other pathogens, in addition to reducing the risks of selecting resistant fungal strains (Meyer et al., 2018).

The second most efficient group in controlling Diplodia leaf streak were products with a mixture of carboxamide + strobilurin and a mixture of triazole + strobilurin. In these mixtures, the control efficiency ranging of 82.20% to 86.06%.

Table 2. Area Under the Disease Progress Curve (AUDPC) and control efficiency (%) of Diplodia leaf streak (*Stenocarpella macrospora*) in hybrid DKB 390 PRO3, after fungicide spraying. Experimental Field EPR, Sorriso – MT, Crop Season 2019/2020.

Trat.	Active Ingredient	g.i.a/ha	AUDPC	(%) Control efficiency
T1	Control	-------	1137,5 e	-
T2	Trifloxystrobin + Ciproconazole	75 + 32	384,5 c	66,20 c
T3	Pyraclostrobin + Mefentrifluconazole	200 + 200	350,0 c	69,23 c
T4	Pyraclostrobin + Fluxapyroxad + Mefentrifluconazole	106.8 + 53.4 + 79.8	83,4 a	92,66 a
T5	Azoxystrobin + Tebuconazole	60 + 100	258,0 b	77,31 b
T6	Pyraclostrobin + Epoxiconazole	78 + 48	270,8 b	76,19 b
T7	Azoxystrobin + Ciproconazole	60 + 24	291,5 b	74,37 b
T8	Azoxystrobin + flutriafol	75 + 75	318,8 b	71,97 b
T9	Picoxystrobin + Ciproconazole	80 + 32	612,0 d	46,20 d
T10	Prothioconazole + Trifloxystrobin	70 + 60	174,3 b	84,67 b
T11	Difenoconazole + Ciproconazole	75 + 45	630,3 d	44,58 d
T12	Fluxapyroxad + Pyraclostrobin	50.1 + 99.9	158,5 b	86,06 b
T13	Bixafen + Prothioconazole + Trifloxystrobin	62.5 + 87.5 + 75	85,4 a	92,49 a
T14	Azoxystrobin + Benzovindiflupyr	60 + 30	202,5 b	82,20 b
T15	Picoxystrobin + Benzovindiflupyr	60 + 30	170,3 b	85,00 b
T16	Azoxystrobin + Difenoconazole + Chlorothalonil	80 + 80 + 1000	370,0 c	67,47 c
	CV (%)		8,35	8,35

Fonte: Autores

Means followed by the same letter in the vertical column do not differ from each other, according to the Schott-Knott test at 5% probability. CV (%) = coefficient of variation.

Carboxamides and strobilurins act protectively, inhibiting the germination of spores and preventing the fungus from penetrating and colonizing the host. According to

Bampi et al. (2012) the application of fungicides preventively guarantees greater control of Diplodia leaf streak, when compared to the application in an eradictive and curative manner. Bampi et al. (2012), when evaluating the performance of fungicides in controlling this disease, they observed that the application of fungicides containing strobilurin + triazole reduced the disease by an average of 75%, while fungicides containing only strobilurin, benzimidazoles and triazole reduced the disease by an average of 62%, 55% and 38% of severity, respectively.Similar results were found by Mendes et al. (2018) where the highest levels of Diplodia leaf streak control were found in treatments with the application of fungicides containing mixtures of strobilurin + triazole and benzimidazole + triazole.

For Southern corn rust, the most effective fungicides in controlling the disease were a mixture of carboxamide + strobilurin (T14 and T15), in association with triazole (T4) or strobilurin associated with triazole (treatment 8) and chlorothalonil (treatment 16), showing control between 93.27% and 97.67% (Table 3).

Similar results were found by Donato and Bonaldo (2013). According to the authors, there was a significant reduction in the severity of Southern corn rust in treatments with the application of a fungicide containing a mixture of strobilurin and triazole (trifloxystrobin + tebuconazole and azoxystrobin + cyproconazole). Moratelli et al. (2015) reported that the application of the fungicide trifloxystrobin + tebuconazole was effective in reducing the severity of Southern corn rust on corn plants. Henriques et al. (2014), when evaluating the application of fungicides at different times to control foliar diseases in popcorn crops, they detected lower AACPD in treatments with the application of pyraclostrobin + epoxiconazole and carbendazim + tebuconazole + cresoxim-methyl, sprayed at phenological stages V8 and R2. According to the authors, the application of fungicides containing molecules with protective action in V8, prevented the infection of pathogens in the leaf for a few days, while the application in R2 renewed the preventive action and acted in a curative manner in phytopathogen infections.

Table 3. Area Under the Disease Progress Curve () in hybrid DKB 390 PRO3 and control efficiency of Southern corn rust (Puccinia polysora), after fungicide spraying. ERP Experimental Field, Sorriso – MT, Crop Season 2019/2020.

Trat.	Active Ingredient	g.i.a/ha	AUDPC	(%) Control efficiency
T1	-------	-------	184,5 f	-
T2	Trifloxystrobin + Ciproconazole	75 + 32	22,1 b	88,02 b
T3	Pyraclostrobin + Mefentrifluconazole	200 + 200	23,9 b	87,04 b
T4	Pyraclostrobin + Fluxapyroxad + Mefentrifluconazole	106.8 + 53.4 + 79.8	12,4 a	93,27 a
T5	Azoxystrobin + Tebuconazole	60 + 100	65,7 d	64,39 d
T6	Pyraclostrobin + Epoxiconazole	78 + 48	74,3 d	59,72 d
T7	Azoxystrobin + Ciproconazole	60 + 24	40,3 c	78,15 c
T8	Azoxystrobin + flutriafol	75 + 75	6,3 a	96,58 a
T9	Picoxystrobin + Ciproconazole	80 + 32	79,9 d	56,69 d
T10	Prothioconazole + Trifloxystrobin	70 + 60	83,3 d	54,85 d
T11	Difenoconazole + Ciproconazole	75 + 45	113,4 e	38,53 e
T12	Fluxapyroxad + Pyraclostrobin	50.1 + 99.9	36,9 c	80,00 c
T13	Bixafen + Prothioconazole + Trifloxystrobin	62.5 + 87.5 + 75	31,5 c	82,92 c
T14	Azoxystrobin + Benzovindiflupyr	60 + 30	5 a	97,29 a
T15	Picoxystrobin + Benzovindiflupyr	60 + 30	11,7 a	93,65 a
T16	Azoxystrobin + Difenoconazole + Chlorothalonil	80 + 80 + 1000	4,3 a	97,67 a
	CV (%)		7,45	7,45

Means followed by the same letter in the vertical column do not differ from each other, according to the Schott-Knott test at 5% probability. CV (%) = coefficient of variation. Fonte: Autores

All fungicide treatments showed higher stalk dry matter weight compared to the control (Table 4). Treatments with a triple mixture containing carboxamide, triazole and strobilurin, T4 (pyraclostrobin + fluxapyroxad + mefentrifluconazole) and T13 (Bixafen + Prothioconazole + trifloxystrobin) provided the highest weights of stalk dry matter among the fungicides evaluated. Similar results were found by Silva (2017), where treatments with carboxamide provide greater grain productivity, greater stalk dry matter weight and greater stalk integrity (densities, amount of lignin and cellulose), reducing breakage.

Table 4. Dry Matter Weight of Stalks (ton/ha) and Incidence of burned grains (%) in Corn Crop, Subjected to Different Fungicide Treatments. EPR, Sorriso-MT, 2020

Trat.	Active Ingredient	g.i.a/ha	Dry Matter Weight of Stalks (ton/ha)	(%) Burned grains
T1	Control	-------	9,17 c	4,70 (NS)
T2	Trifloxystrobin + Ciproconazole	75 + 32	9,94 b	3,90
T3	Pyraclostrobin + Mefentrifluconazole	200 + 200	10,02 b	2,90
T4	Pyraclostrobin + Fluxapyroxad + Mefentrifluconazole	106.8 + 53,4 + 79,8	13,73 a	0,57
T5	Azoxystrobin + Tebuconazole	60 + 100	10,78 b	3,20
T6	Pyraclostrobin + Epoxiconazole	78 + 48	10,41 b	1,77
T7	Azoxystrobin + Ciproconazole	60 + 24	10,51 b	3,47
T8	Azoxystrobin + flutriafol	75 + 75	10,12 b	3,55
T9	Picoxystrobin + Ciproconazole	80 + 32	9,99 b	4,60
T10	Prothioconazole + Trifloxystrobin	70 + 60	9,92 b	1,22
T11	Difenoconazole + Ciproconazole	75 + 45	10,28 b	3,98
T12	Fluxapyroxad + Pyraclostrobin	50,1 + 99,9	10,19 b	1,22
T13	Bixafen + Prothioconazole + Trifloxystrobin	62,5 + 87,5 + 75	13,07 a	1,00
T14	Azoxystrobin + Benzovindiflupyr	60 + 30	10,19 b	2,30
T15	Picoxystrobin + Benzovindiflupyr	60 + 30	11,18 b	2,22
T16	Azoxystrobin + Difenoconazole + Chlorothalonil	80 + 80 + 1000	10,00 b	3,57
	CV (%)		9,45	5,25

(NS) - Not significant by F test ($p < 0.05$). Means followed by the same letter in the vertical column do not differ from each other, according to the Schott-Knott test at 5% probability. CV (%) = coefficient of variation. Fonte: Autores

The incidence of burned grains did not differ significantly between them. However, variations from 0.57 to 4.70 were observed, showing that the adoption of the use of fungicides can contribute to a reduction in incidence. This percentage of burned grains can be considered low, compared to the results obtained by Neto et al. (2018a), who found in their work carried out under field conditions, 17.88% of corn grains burned in the control, while in fungicide treatments these values ranged by 5.27% to 6.93%

In all treatments and even in the control without application of fungicides, the percentage of burned grains was lower than the limit tolerated by the Ministry of

Agriculture and Livestock, for commercialization, which allows up to 6% of burned grains (Senar, 2017). This fact may be related to environmental conditions unfavorable to infection in the cob, during the reproductive and pre-harvest phase of corn, in the period from May 25th (Figure 1), when the corn plants were at the beginning of the cob formation, on June 15th, in the pre-harvest phase, relative air humidity was recorded between 46% and 83%. According to ROCHA et al., (2020) the ideal condition for the infection of most fungal species on cobs, in the field, is relative humidity between 90% and 100%. This fact did not occur in the present study, which corroborates a satisfactory value.

In the incidence of phytopathogenic fungi in burned corn grains, there was a predominance of *S. macrospora*, with incidences between 27.29% and 84.35% and of *Fusarium* sp. with incidences between 10.16% and 68.12% (Table 5). The species *S. maydis* was also detected, but at a lower incidence, ranging from 0.62% to 17.50%. The fungi *Penicillium* sp. and *Aspergillus* sp., presented a maximum incidence of 5.84% and 1.46%, respectively. According to Catão et al. (2013), these fungi cause greater damage to stored grains.

Regarding the *Stenocarpella* species involved in the infectious process of corn cobs, it was observed that *S. macrospora* was the most common, with an average incidence of 75.5%. Behavior similar to that observed by Mário and Reis (2003). According to the authors, the higher incidence of *S. macrospora* compared to *S. maydis* in burned grains can be explained by the fact that *S. macrospora* also infects the leaves. Infection at the base of the ears may originate from inoculum produced on leaf lesions and transported by water to the leaf sheath (Casa et al., 2006), which later germinate and initiate infection at the base of the ear (Casa, 2000).

Another factor that may have influenced the greater occurrence of *S. macrospora* in relation to *S. maydis* is the climatic conditions. The geographic distribution of *S. macrospora* is most common in regions with a tropical and subtropical climate (Johann, 1935), with temperatures between 25 and 32 ºC (Eddins, 1930) and relative humidity above 50% (Latterell et al., 1983), which are ideal for the release and germination of conidia.

The treatments T2 (trifloxystrobin + cyproconazole), T9 (picoxystrobin + cyproconazole), T12 (fluxapyroxad + pyraclostrobin) and T16 (azoxystrobin + difenoconazole + chloratolonil) showed the highest incidence values of *S. macrospora* in the burned grains, differing significantly from the control treatment. The positive effect of strobilurins on plant growth and biomass production is clearly known, with action delaying leaf senescence, increasing nitrate absorption, and regulating phytohormonal levels to overcome stress and alleviate plant oxidative stress (Kanungo and Joshi, 2014; Wise and Mueller, 2011). However, it is necessary to evaluate the greater susceptibility provided using fungicides with strobilurins in mixture to the infection of phytopathogens that cause burned grains such as *S. macrospora*.

Stefanello et al. (2012) did not observe a significant response from the application of the fungicide Azoxystrobin + Cyproconazole, in the aerial part of corn hybrids, on the incidence of *Penicillium* sp. and *Aspergillus* sp. in the grains. However, in our study, treatments with a mixture of strobilurins, T3 (pyraclostrobin + mefentrifluconazole); T8 (azoxystrobin + flutriafol), T10- (Prothioconazole + trifloxystrobin) and T15 (picoxystrobin + Benzovindiflupyr) showed incidences of *Penicillium* sp. significantly higher than the control.

The effectiveness of the fungicides Azoxystrobin + Benzovindiflupyr and Picoxystrobin + Cyproconazole in reducing the incidence of *Penicillium* spp. in corn grains were also observed by Neto et al. (2018a), where the spraying of fungicides promoted greater control of the fungus. Neto et al (2018b) detected lower incidences of *Penicillium* spp. in the fungicide treatment Azoxystrobin + Benzovindiflupyr. As in this study, lower incidences of the fungus were observed in the treatments Azoxystrobin + Benzovindiflupyr and Picoxystrobin + cyproconazole, which did not differ statistically from the fungicide treatments Trifloxystrobin + Cyproconazole, Pyraclostrobin + Fluxapyroxad + mefentrifluconazole, Azoxystrobin + Tebuconazole, Pyraclostrobin + Epoxiconazole, Azoxystrobin + Cyproconazole , Picoxystrobin + Cyproconazole, Fluxapyroxad + Pyraclostrobin, Bixafen + Prothioconazole + Trifloxystrobin, Azoxystrobin + Benzovindiflupyr and the control.

Table 5. Table 5. Incidence of Fungi (%) in Burned grains corn, Subjected to Treatments with Foliar Fungicide Spraying. EPR, Sorriso-MT, 2020."

Trat	Active Ingredient	g.i.a/ha	*S. macrospora*	*S. maydis*	*Fusarium* sp.	*Penicillium* sp.	*Aspergillus* sp.	*A. flavus*
T1	-------	-------	63,90 b	11,83 a	24,26 c	0,00 b	0,00 a	0,00 a
T2	Trifloxystrobin + Ciproconazole	75 + 32	84,35 a	4,38 b	10,16 d	0,00 b	0,00 a	0,00 a
T3	Pyraclostrobin + Mefentrifluconazole	200 + 200	53,79 c	9,45 a	28,06 c	3,29 a	0,32 a	0,00 a
T4	Pyraclostrobin + Fluxapyroxad + Mefentrifluconazole	106,8 + 53,4 + 79,8	62,04 b	6,31 b	28,73 c	1,25 b	0,00 a	0,00 a
T5	Azoxystrobin + Tebuconazole	60 + 100	56,81 c	1,17 b	40,56 b	1,00 b	0,67 a	0,00 a
T6	Pyraclostrobin + Epoxiconazole	78 + 48	47,00 d	17,50 a	36,12 b	1,00 b	0,00 a	0,00 a
T7	Azoxystrobin + Ciproconazole	60 + 24	30,58 f	8,73 a	59,81 a	0,00 b	0,00 a	0,00 a
T8	Azoxystrobin + flutriafol	75 + 75	34,72 e	11,07 a	48,37 b	5,84 a	0,00 a	1,00 a
T9	Picoxystrobin + Ciproconazole	80 + 32	83,50 a	3,72 b	12,46 d	0,31 b	0,32 a	10,32 a
T10	Prothioconazole + Trifloxystrobin	70 + 60	58,67 c	3,85 b	32,95 c	3,90 a	0,00 a	0,00 a
T11	Difenoconazole + Ciproconazole	75 + 45	27,29 f	1,04 b	68,12 a	3,54 a	0,00 a	0,00 a
T12	Fluxapyroxad + Pyraclostrobin	50,1 + 99,9	77,24 a	0,62 b	20,89 c	0,00 b	0,00 a	0,00 a
T13	Bixafen + Prothioconazole + Trifloxystrobin	62,5 + 87,5 + 75	37,50 e	2,92 b	57,50 a	0,42 b	0,00 a	0,00 a
T14	Azoxystrobin + Benzovindiflupyr	60 + 30	67,50 b	3,85 b	26,15 c	1,35 b	0,00 a	0,00 a
T15	Picoxystrobin + Benzovindiflupyr	60 + 30	49,47 d	2,31 b	44,15 b	4,93 a	0,00 a	1,32 a
T16	Azoxystrobin + Difenoconazole + Chlorothalonil	80 + 80 + 1000	77,60 a	6,15 b	16,25 d	0,00 b	7,00 a	0,00 a
	CV (%)		5.37	38.15	11.24	35.85	51.68	60.52

Means followed by the same letter in the vertical column do not differ from each other, according to the Schott-Knott test at 5% probability. CV (%) = coefficient of variation. Fonte: Autores

Regarding productivity, control and treatments with fungicides Picoxystrobin + Cyproconazole and Difenoconazole + Cyproconazole, presented the lowest productivity, differing significantly from the other treatments (Table 6). Treatments T4 (pyraclostrobin + fluxapyroxad + mefentrifluconazole), T12 (fluxapyroxad + pyraclostrobin), T13 (Bixafen + prothioconazole + trifloxystrobin), T14 (azoxystrobin + Benzovindiflupyr), T15 (picoxystrobin + Benzovindiflupyr) and T16 (azoxystrobin + difenoconazole + chloratolonil) provided yields significantly higher than the control, treatments that provided the best control of Diplodia leaf streak or pollard rust, indicating the importance of maintaining the photosynthetic area of the leaf in final productivity. The explanation for this fact is because strobilurins are activators of the nitrate reductase enzyme, which would contribute to the maintenance of chlorophyll pigments and thus regulation of photosynthetic activity, contributing to greater productivity. Similar results were found by Barbosa et al. (2012) with treatment using strobirulins as fungicides in fungi control. In relation to PMS, no significant difference was observed between treatments, which demonstrates that the hybrid used is tolerant to leaf spots and is thus capable of maintaining the physiological and biochemical processes of photosynthesis intact (Table 6).

Table 6. Table 6. Productivity of Corn Crop and TKW (Thousand Kernel Weight) subjected to different treatments with fungicides spraying, composed of the chemical groups of triazoles, strobilurins, dithiocarbamates, and carboxamides. EPR, Sorriso-MT, 2020.

Trat.	Active Ingredient	g.i.a/ha	Productivity ($kg.ha^{-1}$)	TKW (g)
T1	Control	-------	7,500.0 c	373.50 ^{ns}
T2	Trifloxystrobin + Ciproconazole	75 + 32	8,302.8 b	389.00
T3	Pyraclostrobin + Mefentrifluconazole	200 + 200	8,244.0 b	382.50
T4	Pyraclostrobin + Fluxapyroxad + Mefentrifluconazole	106.8 + 53.4 + 79,8	8,656.2 a	401.00
T5	Azoxystrobin + Tebuconazole	60 + 100	8,574.0 b	390.00
T6	Pyraclostrobin + Epoxiconazole	78 + 48	8,550.0 b	385.00
T7	Azoxystrobin + Ciproconazole	60 + 24	8,522.4 b	395.00
T8	Azoxystrobin + flutriafol	75 + 75	8,562.0 b	374.50
T9	Picoxystrobin + Ciproconazole	80 + 32	7,636.2 c	360.00
T10	Prothioconazole + Trifloxystrobin	70 + 60	8,419.2 b	379.50
T11	Difenoconazole + Ciproconazole	75 + 45	7,735.2 c	375.00
T12	Fluxapyroxad + Pyraclostrobin	50.1 + 99.9	8,765.4 a	396.00
T13	Bixafen + Prothioconazole + Trifloxystrobin	62.5 + 87.5 + 75	8,823.0 a	399.00
T14	Azoxystrobin + Benzovindiflupyr	60 + 30	8,828.4 a	399.00
T15	Picoxystrobin + Benzovindiflupyr	60 + 30	8,841.6 a	392.50
T16	Azoxystrobin + Difenoconazole + Chlorothalonil	80 + 80 + 1000	8,811.0 a	394.00

CV (%)	5.20	5.67

Means followed by different letters in the column differ from each other according to the Schott-Knott test at 5% probability. ns - Not significant; CV (%) = coefficient of variation
Fonte: Autores

4 CONCLUSÃO

Fungicides sprayed with a triple mixture of carboxamide, triazole and strobilurin showed greater efficiency in controlling Diplodia leaf streak. The lowest severity of Southern corn rust was observed in treatments with a mixture of carboxamide + strobilurin, in association with triazole or strobilurin in association with triazole and chlorothalonil.

Corn productivity was higher in treatments with mixture T4 and T12-T16, with a range of 8,787.6 kg ha^{-1} to 8,811.0Kg ha^{-1}, overcoming the control (7,500.0 kg ha^{-1}). The applying of fungicides did not significantly influence the incidence of burned grains and the main fungi associated with burned grains were *S. macrospora* and *Fusarium* sp.

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