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EVALUATION OF DIFFERENT FUNGICIDES IN PHYTOSANITARY MANAGEMENT FOR THE CONTROL OF SEPTORIA GLYCINES AND CERCOSPORA KIKUCHII IN SOYBEAN CROPS

AVALIAÇÃO DE DIFERENTES FUNGICIDAS, PROTETORES E INDUTORES DE RESISTÊNCIA NO MANEJO FITOSSANITÁRIO PARA O CONTROLE DE SEPTORIA GLYCINES E CERCOSPORA KIKUCHII NA CULTURA DA SOJA

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Abstract

Soybean yield can be affected by several factors, one of which is diseases such as septoriosis andercosporiosis, which can drastically reduce soybean yield. The objective of this study was to evaluate the efficiency of controlling the associations of different fungicides with protective and resistance-inducing products in the management of Septoria glycines and Cercospora kikuchii, which can affect the production components of the soybean crop. The experiment was carried out in a randomized block design (DBC) in Perobal – PR, Brazil, with 6 treatments related to the association of different fungicides with protectants and resistance inducers, applied to soybean crops with 5 replications. The first application of the treatments was performed at the V5 stage, the second application was 15 days after the first application, the third application 15 days after the second application, and the fourth and last application was 15 days after the third application. The evaluations were carried out 15 days after the last application, and the crop was at the R6 stage, where severity, number of pods per plant, weight of one thousand grains and yield were evaluated. The treatments that obtained the best performance for the control of septtoriosis and brown eye spot were the use of the combination of the active ingredients used in T2 (mancozeb + prothioconazole + bixafen + trifloxystrobin) and T6 (difenoconazole + propiconazole + cyproconazole + picoxystrobin + curative). The use of the curative resistance inducer containing copper and nickel (T6) has been shown to be efficient in the control of Septoriosis and Cercosporiosis and may be recommended to help in the control of these diseases, while the inducer used in the (T5) based on jasmonic and salicylic acid was not efficient.

Resumo

A produtividade da soja pode ser afetada por diversos fatores, um destes fatores são as doenças como a Septoriose e a Cercosporiose que podem reduzir drasticamente a produtividade da soja. O objetivo do trabalho foi avaliar a eficiência de controle das associações de diferentes fungicidas, com produtos protetores e indutores de resistência no manejo de Septoria glycines e Cercospora kikuchii que podem afetar os componentes de produção na cultura da soja. O experimento foi conduzido sob o delineamento experimental de blocos casualizados (DBC), em Perobal – PR, sendo 6 tratamentos relacionados a associação de diferentes fungicidas com protetores e indutores de resistência, aplicados na cultura da soja com 5 repetições. A primeira aplicação dos tratamentos foi realizada no estádio V5, a segunda aplicação foi após 15 dias da primeira aplicação, a terceira aplicação 15 dias após a segunda aplicação, a quarta e última aplicação foi 15 dias após a terceira aplicação. As avalições foram realizadas 15 dias após a última aplicação, a cultura estava no estádio R6, onde avaliou-se severidade, número de vagens por planta, massa de mil grãos e produtividade. Os tratamentos que obtiveram melhor performance para o controle de Septoriose e cercosporiose, foi o uso da associação dos princípios ativos utilizados no T2 (mancozeb + protioconazole + bixafen + trifloxistrobina) e T6 (difenoconazol + propiconazol + ciproconazol + picoxistrobina + curative). O uso do indutor de resistência curative contendo cobre e níquel (T6), demonstrou ter eficiência no controle de Septoriose e Cercosporiose, podendo ser recomendado para ajudar no controle destas doenças, já o indutor utilizado no (T5) a base de ácido jasmônico e salicílico não se mostrou eficiente.

INTRODUCTION

Soy is considered one of the most important crops due to its large amount of protein, which is of excellent quality for animal feed and oil production for human consumption (FEDERIZZI, 2005).

However, there are still challenges in achieving the maximum productivity potential of soybean varieties due to biotic and abiotic factors (NAVARRO; COSTA, 2002). Among these factors, diseases play a crucial role and pose a threat to increasing productivity in soybean crops. It is estimated that more than 40 pathogens have been identified in crops in Brazil, which have the potential to limit crop production (TECNOLOGIAS, 2013).

Soybean productivity can be affected by several biotic and/or abiotic factors . End-of-cycle diseases (CLDs) include brown spot and cercospora leaf blight (BALARDIN, 2002). These diseases are considered important due to their ability to reduce soybean yield. A positive relationship between rainy years and high severity of CFD has been observed. This group of pathogens, after being introduced into crops, can survive in crop residues (YORINORI, 1994, 1999), in addition to being transmitted by seeds or inoculated through wind and rain.

Septoria and leaf blight of Cercospora and purple spot, because they generally occur at the same time and present difficulties for individual assessments, are known as a complex of end-of-cycle diseases (CLD) (MARTINS, 2004).

Septoria, also known as brown spot, is caused by the fungus *Septoria glycines Hemmi*, and Septoria symptoms on the leaves may appear approximately two weeks after the plants emerge as small reddish-brown spots or spots with angled edges (ITO, 1993).

Cercospora leaf blight and purple seed spot are caused by the fungus *Cercospora kikuchii*, and its incidence is favored by hot and humid conditions, from full flowering to physiological maturity of soybeans (FAO, 1995). Soybean seeds colonized by *Cercospora kikuchii* may present a reduction in their germination capacity, in addition to giving rise to less vigorous and less productive seedlings (MORAIS, 2022).

The use of foliar fungicides is one of the main strategies adopted to control diseases in soybean crops. This protective measure is essential to prevent pathogen infection during the plant's period of greatest vulnerability, which ranges from the beginning of flowering or interrow closure to the beginning of pod formation (MEYER et al., 2017). One of the main challenges for soybean cultivation is the phytosanitary management of diseases (FONSECA & ARAÚJO, 2015).

The most popular fungicides are known by the control principle, mobility, spectrum, mode of action and chemical group (ARAUJO, 2021). However, caution is needed when applying fungicides, as there are problems with the emergence of fungicide-resistant disease populations. Therefore, the alternating use of fungicides from different action groups is recommended (ITO, 2013).

Risk factors leading to the emergence of disease-resistant fungicides in the field may be the prolonged and frequent use of fungicides containing the same active ingredient. The risk associated with the administration of fungicides is due to the long and unfavorable contact times of the product with fungi, lack of mixing or alternation of the active ingredient, or doses outside the leaflet recommendations and widespread use. same product (ZAMBOLIM, 2008).

Researchers recommend the application of mixtures of different active ingredients with protective and multisite fungicides, with the aim of enhancing the effectiveness of fungicides that already show resistance and preserving active ingredients for which resistance has not yet been documented (ALVES, 2018).

The induction of resistance in plants has been worked on as an alternative to stimulate natural mechanisms, where salicylic acid translocates and “prepares” the plant for infection, so that there is a quick and efficient response when something tries to parasitize it (TORREZAN, 2023). Multisites/protectors, on the other hand, function through contact activity and do not translocate in the plant (FRAC, 2022). They should be used preventively; before infections develop, protectants can help preserve the effectiveness of other fungicide molecules, given the potential development of resistance of disease-causing fungi to active ingredients (CARVALHO, 2023).

It is of great importance to have knowledge of the diseases that affect soybeans and to understand their control, with different phytosanitary management options that can maximize grain production.

Phytosanitary management prevents or controls the development of fungal diseases in soybean crops, which can reduce grain productivity and quality. Fungicides act by preventing the development of the fungus or eliminating it (FANCELLI & DOURADO-NETO, 2011), and the application of fungicides can increase soybean productivity. This is because diseases can reduce the number of pods, the mass of beans per pod, and the weight of the beans. With correct management, the plant is protected and can maintain its productive potential (BALARDIN et al., 2013).

The objective of the work was to evaluate the efficiency of the association with various fungicides, protective products and resistance inducers in the control of *Septoria glycines* and *Cercospora kikuchii* and in the production components in soybean crops that may be affected by these diseases.

MATERIALS AND METHODS

The experiment was installed in the 2022/2023 harvest on a property located in the municipality of Perobal-PR, whose geographic coordinates are 23°54'56”S, 53°28'48”W, and has an average altitude of 338 meters. The climate is classified as mesothermal humid subtropical (Cfa), and the soil in the experimental areas is classified as a dystrophic red–yellow latosol with a sandy texture (EMBRAPA, 2006). Based on the analysis, the physical characteristics of the soil were 18.75% clay, 13.75% silt and 67.50% sand.

The experiment was conducted under a randomized block design (DBC), with 6 treatments and 5 replications, sown at a density of 266,000 seeds per ha $^{-1}$, the spacing used was 0.45 m, the cultivar used was DM66I68RSF IPRO, sown on October 15, 2022, and each experimental plot had an area of 15 m ^{2}, 6 sowing lines 5 m long (5 m x 3 m).

The treatments used were first, with (T1) where it served as a control as no management was carried out, T2 with the first application of difenoconazole + propiconazole, the second application with prothioconazole + bixafen + trifloxystrobin + mancozeb, the third and fourth application cyproconazole + trifloxystrobin + mancozeb; T3 was used the first application of difenoconazole + propiconazole, the second and third application of flurapyroxad + epoxiconazole + pyraclostrobin + copper oxychloride, and the fourth application of cyproconazole + picoxystrobin + copper oxychloride; T4 the first application of difenoconazole + propiconazole, the second and third application was tebuconazole + impirfluxam + mancozeb and the fourth application was cyproconazole + picoxystrobin + mancozeb; T5 the first application of difenoconazole + propiconazole, the second application was flurapyroxad + pyraclostrobin + cuprous oxide + salicylic acid + jasmonic acid , the third application was cyproconazole + picoxystrobin + cuprous oxide + salicylic acid + jasmonic acid and the fourth application was cyproconazole + difenoconazole + cuprous oxide + salicylic acid + jasmonic acid; T6 in the first application difenoconazole + propiconazole, in the second application cyproconazole + picoxystrobin + curative and in the third and fourth application cyproconazole + difenoconazole + curative. The doses of all products used follow the recommended dose on the leaflet.

Because the experiment was installed on a commercial farm, some management was carried out by the producer, but the same in both treatments, including fertilization in the sowing furrow with 227 kg per ha-¹ of NPK 03-21-21 and inoculation in the furrow with *Bradyrhizobium japonicum and B. elkanii* (5x10 ^{9} CFU mL $^{-1}$ at a dose of 300 mL ha $^{-1)}$ and *Azospirillum brasilense* (strains abv5 and abv6 with a concentration of 2x10 ^{8} CFU mL $^{-1}$ at a dose of 150 mL ha $^{-1}$). At stage V4, Stimulate® (4-indole-3ylbutyric acid 0.05 g ha-1 + kinetin 0.09 g ha $^{-1}$ + gibberellic acid) was applied. Four acephate applications were carried out (1,164 g ai ha $^{-1}$).

The applications in the treatments were carried out with a knapsack sprayer equipped with six XR 110.02 fan tips under a pressure of 2.0 kgf cm $^{-2}$. These application conditions provided the equivalent of 200 L ha-¹ of syrup. The first application of the treatments was carried out at stage V5, the second application was 15 days after the first application, the third application was 15 days after the second application, and the fourth and final application was 15 days after the third application.

The severity assessment of *Septoria glycines and Cercospora kikuchii* was carried out 15 days after the 4th application, the culture was at the R6 stage, and to evaluate it, a diagrammatic scale of end-of-cycle diseases (CFD) of soybean prepared by MARTINS et al was used. ., (2004) (Figure 1), where 10 plants collected at random per plot were evaluated.

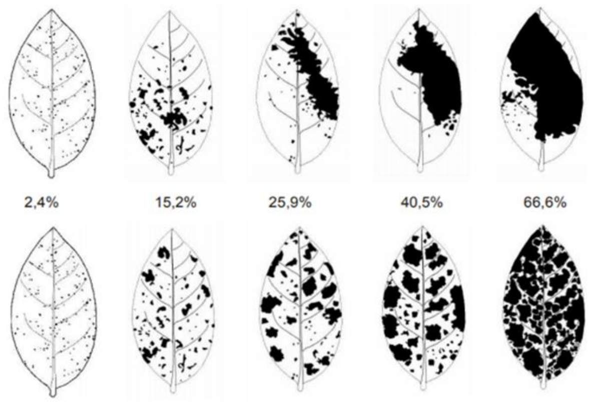

Figure 1. Diagrammatic scale of soybean end-of-cycle diseases (CFD) prepared by MARTINS et al., 2004

The evaluations of the number of pods, thousand grain mass (MMG) and productivity kg ha $^{-1}$ were performed when the crop reached the R9 stage. To evaluate the number of pods, plants from the 3rd and 4th rows were collected per 1 linear meter of each treatment, with 5 repetitions being made for each treatment. Each repetition had a collection interval of 3 meters from each other and 3.40 meters from the borders.

The mass of one thousand grains (MMG) and productivity kg ha $^{-1}$ were measured after threshing with a stationary threshing machine, in which weighings were carried out with 10 repetitions of 100 grains each treatment, and at the end of the weighing, the average MMG of each was obtained. treatment.

For productivity, two central lines, third and fourth lines, were harvested per treatment, deducting 1.5 m from each border, totaling a harvested area of 2.7 m² (1.35 mx 2 m). After that, the plants were threshed, and the grain mass obtained was classified, discounting moisture and impurities, and using the net weight, productivity was calculated, with productivity equivalent to kg ha $^{-1}$.

The data were submitted to the SISVAR program with analysis of variance using the F test, and when significant, the means were submitted to the Tukey test at 5% probability.

RESULTS AND DISCUSSION

With the use of different mixtures of site-specific fungicides, resistance inducers and multisite fungicides, different responses can be observed in relation to the control of *Septoria glycines* and *Cercospora kikuchii* and the other factors evaluated in the work (Table 1).

Table 1. Assessment of severity, number of pods per plant, mass of one thousand grains (g) and productivity (kg ha $^{-1}$) of the different treatments for the control of *Septoria glycines* and *Cercospora kikuchii* in soybean crops.

	Severity	**Number of pods per plant**	**MMG (g)**	**Productivity (kg ha $^{-1}$)**
T1	66.60d	42.80b	160.86b	2695.82b
T2	15.20 to	50.20 to	190.79 a	3480.00 to
T3	45.72c	46.20 ab	180.63 ab	2733.33b
T4	28.82b	47.80 ab	180.05 ab	3100.00b
T5	21.62 ab	48.60 to	180.59 ab	3117.78b
T6	15.20 to	50.80 to	170.97 ab	3468.89 ab

As the table shows, the treatments that had less severity, a greater number of pods and more significant productivity were treatments 2 and 6. One of the points that these two treatments have in common is the use of cyproconazole, which in T2 was present in the third and fourth application and at T6 from the second to fourth application.

Cyproconazole is one of the most commonly used triazoles to control diseases in soybean crops in Brazil and one of the oldest, and for these diseases, it still has a good level of control; however, to have this efficiency, it must always be associated with a strobirulin, carboxamide and even another triazole, as well as in treatments 6, and as in the work of SOUZA et al. (2021), who evaluated different types of fungicides in the control of end-of-cycle diseases, where cyproconazole in a mixture proved to be efficient in the control of *Septoria glycines* and *Cercospora kikuchii.*

In T6, the use of another triazole in 3 applications was difenoconazole. The effectiveness of difenoconazole in controlling septoria and cercosporiosis is recognized by its systemic activity and slower translocation in the plant, meaning that it stays longer to protect the leaves, thus improving control efficiency (SILVA, 2019).

Another point that helps explain the efficiency of T6 was the use of a curative, which is a resistance inductor based on copper and nickel. Copper participates in numerous biochemical and physiological reactions, is an activator or component of enzymes, and acts in photosynthesis and transpiration of the plant, thus helping to control diseases (SATIS, 2023). Nickel, in turn, plays a role in the photosynthesis process and is a cofactor of the enzyme superoxide dismutase, which protects the plant against oxidative damage, making the plant more resistant to diseases (MY FARM, 2023).

In the case of treatment 5, a resistance inducer was also used, which in its formulation contains low concentrations of copper, salicylic and jasmonic acid, having a lower efficiency in controlling septoria and cercosporiosis in relation to other resistance inducers.

Salicylic acid and jasmonic acid activate systemic and local defense mechanisms and produce phytoalexins, which are the plant's natural defense compounds. This type of resistance induction has shown promise for controlling other diseases, but for septoria and cercosporiosis, it has not been shown to be efficient (SANTOS, 2021).

ANDRADE (2019), in his experiment, evaluated different fungicides in the control of *Septoria glycines* in soybean crops, in which the application of Cu-based products proved to be efficient in controlling septoria and cercosporiosis, data that corroborate the present work.

These results differ from the work of GABARDO et al. (2020), who evaluated alternative products for the control of end-of-cycle diseases in soybeans and concluded that the acibenzolar-S-methyl resistance inducer, the product alternatives (calcium, copper, manganese, zinc and molybdenum) and *A. nodosum* had no effect on the severity of CLD in the two harvests.

In T2, in addition to lower severity and higher productivity (Table 1), another factor that drew attention was the mass of one thousand grains, as it was the treatment that obtained the highest mass. One of the factors that can help explain this greater grain mass is the use of a mixture of multisite fungicides during applications and the use in the second application of products containing prothioconazole, which belongs to the group of triazolinthiones, and containing bixafen, which is from the carboxamide group. The mechanism of action of mancozeb is associated with the prevention of respiration and photosynthesis of pathogens, which results in the prevention and control of the development of the fungus. The mechanism of action of prothioconazole inhibits the synthesis of ergosterol in the fungus, and bixafen inhibits the synthesis of ATP (SANTOS, 2020).

According to GOMES et al. (2019) and SILVA et al. (2020), prothioconazole and bixafen have been effective in controlling septoria when applied preventively or in the initial stages of infection.

BLANC (2018), in his work, evaluated the chemical control of leaf spots in different soybean cultivars, where he describes that the different fungicide treatments influenced the MMG, and in the treatments that presented the highest MMG, contained at least one application of mancozeb and one of bixafen, corroborating the present work.

Embrapa's technical circular 193 of the year 2023 evaluated the efficiency of fungicides for the control of soybean end-of-cycle diseases. In the 2022/2023 harvest, the trials were carried out cooperatively in 14 research institutions spread across Brazil, and in these trials, the highest productivity was observed for treatments with mancozeb + picoxystrobin + prothioconazole, adding 5 to 8% more control compared to treatments without the mixture of mancozeb + prothioconazole and obtaining a productivity of 17% to more than the witness (EMBRAPA, 2023), results that corroborate the present work.

The continuous application of fungicides with a single active ingredient promotes selective pressure and allows resistant strains to dominate the pathogen population (BIGOLIN, 2015). Controls carried out by site-specific fungicides such as respiration inhibitors in complex 2, succinate dehydrogenase (SDHI), have a greater impact on the development of resistance to phytopathogenic fungi. In this context, the application of site-specific fungicides mixed with fungicides from other chemical groups constitutes a basic strategy in resistance management (SIEROTZKI; SCALLIET, 2013).

Furthermore, according to JULIATTI et al. (2015), the triple mixture can perform a wide range of actions not only against rust but also against a wide range of diseases and to prevent resistance associated with systemic fungicides.

Tebuconazole is a molecule that has already been widely used to control septoria and blind spots in soybeans, being one of the first molecules to be used to control septoria and blind spots. In the work of PICININI AND FERNANDES (1999), in treatments involving the application of tebuconazole, the severity of cercosporiosis and septoria was approximately 30%, similar to the present study.

However, when compared to the results of GODOY et al., (2021) , with the use of tebuconazole to control cercosporiosis and septoria, its efficiency was 33%. Compared to the treatment that had better efficiency, it had a decrease of 21% in the control, and the treatment in this trial that had the greatest efficiency was that containing bixafen + prothioconazole + trifloxystrobin, corroborating the present work.

In T4, products with tebuconazole associated with carboxamides and multisites were applied and obtained medium severity levels, as it was not the treatment where the lowest efficiency was achieved, but it was also not the treatment where the best performance was achieved.

However, it is important to consider that the efficiency of tebuconazole in controlling septoria and cercosporiosis may vary according to factors such as the dosage applied, the time of application, climatic conditions and the resistance of the fungus to certain fungicides (ALMEIDA, 2021).

Treatments that used picoxistobrin and pyraclostrobin, even with a mixture of multisites or inducers, also had average results in controlling septoria and cercosporiosis.

In the work of SOUZA et al. (2021), the severity of C. *ercospora* in the control with the application of Fox Xpro (T2 – 14%) did not differ from the severity of treatments 4 (picoxystrobin + cyproconazole).

CONCLUSIONS

The treatments that achieved the best performance in the 22/23 harvest for the control of Septoriosis and cercosporiosis were the use of a combination of active ingredients used in T2 (mancozeb + prothioconazole + bixafen + trifloxystrobin) and T6 (difenoconazole + propiconazole).
cyproconazole + picoxystrobin + curative), bringing significant results in productivity.

The use of curative resistance inductors containing copper and nickel (T6) has been shown to be effective in controlling Septoriosis and Cercosporiosis and can be recommended to help control these diseases, whereas the inductors used in (T5) are based on jasmonic acid and salicylic acids and were not effective.

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