Ciência Rural, Santa Maria, v.54:12, e20230541, 2024
http://doi.org/10.1590/0103-8478cr20230541
ISSNe 1678-4596
CROP PROTECTION

Alternative products isolated and associated with fungicide at different sowing times to control soybean powdery mildew

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ABSTRACT: Soybean (*Glycine max*) is the most important legume cultivated in the world. With the aim of studying alternative products isolated and associated with fungicide on the efficiency of controlling powdery mildew (*Microsphaera diffusa*), in two sowing seasons, field experiments were conducted in Ponta Grossa, PR, Brazil, during the 2016/2017 and 2017/2018 seasons. The treatments were: 1- control (water), 2- *Bacillus subtilis* lineage QST, 3- *Bacillus subtilis* lineage QST associated with fungicide, 4- 1% chitosan, 5- 1% chitosan associated with fungicide, 6- sulfur, 7- sulfur associated with fungicide, 8- sodium hypochlorite, 9- sodium hypochlorite associated with fungicide, 10- fungicide (2 applications) and 11- fungicide (3 apllications). In all fungicide treatments, azoxystrobin + benzovindiflupyr with adjuvant was used. The variables evaluated were: powdery mildew severity and yield. The severity data made it possible to calculate the area under the disease progress curve (AUDPC). AUDPC values were higher in the second sowing season. Sulfur, chitosan and *B. subtilis*, isolated, reduced AUDPC, but when associated with the fungicide they obtained superior results. Sulfur, whether or not associated with the fungicide, provided less severity of the disease. The fungicide applied three times showed better control than two applications. The highest yield averages were, obtained in the first sowing season. There was no difference between the treatments during sowing in October for yield, this was affected by the treatments, only in the second sowing season, highlighting the sulfur associated with the fungicide.
Key words: *Glycine max*, *Microsphaera diffusa*, sulfur, chitosan, yield.

Produtos alternativos isolados e associados a fungicida em diferentes épocas de semeadura no controle do oídio da soja

RESUMO: A soja (*Glycine max*) é a mais importante leguminosa cultivada no mundo. Com o objetivo de estudar produtos alternativos isolados e associados a fungicida sobre a eficiência do controle do oídio (*Microsphaera diffusa*), em duas épocas de semeadura, foram conduzidos experimentos a campo em Ponta Grossa, PR, Brasil, durante as safras 2016/2017 e 2017/2018. Os tratamentos foram: 1- testemunha (água), 2- *Bacillus subtilis* linhagem QST, 3- *Bacillus subtilis* linhagem QST associado a fungicida, 4- quitosana 1%, 5- quitosana 1% associado a fungicida, 6- enxofre, 7- enxofre associado a fungicida, 8- hipoclorito de sódio, 9- hipoclorito de sódio associado a fungicida, 10- fungicida (2 aplicações) e 11- fungicida (3 aplicações). Em todos os tratamentos com fungicida foi utilizado azoxistrobina + benzovindiflupir com adjuvante. As variáveis avaliadas foram: severidade do oídio e produtividade. Os dados de severidade possibilitaram o cálculo da área abaixo da curva do progresso da doença (AACPD). Os valores da AACPD foram maiores na segunda época de semeadura. O enxofre, a quitosana e *B. subtilis*, isolados reduziram a AACPD, porém quando associados ao fungicida obtiveram resultados superiores. O enxofre, associado ou não ao fungicida proporcionou menor severidade da doença. O fungicida aplicado três vezes, apresentou controle superior a duas aplicações. Obtiveram-se as maiores médias de produtividade na primeira época de semeadura. Não houve diferença entre os tratamentos na semeadura em outubro para a produtividade, esta foi afetada pelos tratamentos, apenas na segunda época de semeadura, destacando-se o enxofre associado ao fungicida.
Palavras- chave: *Glycine max*, *Microsphaera diffusa*, enxofre, quitosana, produtividade.

INTRODUCTION

Glycine max (L.) Merril soybean is the most cultivated oilseed in the world (USDA, 2023). Brazil is the world's largest producer of this grain (DA SILVA et al., 2021). However, the occurrence of diseases is a limiting factor for high crop yields (HENNING et al., 2014).

Powdery mildew, caused by the fungus *Microsphaera diffusa* Cke. & Pk., develops on the leaf surface, forming a thin layer of mycelium (XAVIER et al., 2015), reducing the photosynthetically active area of the plant by up to 50%, leading to drying and premature leaf fall in severe cases, causing damage ranging from 10 to 40% (JIANG et al., 2019).

There are moderately resistant cultivars; however, there is great variation in the reaction of genotypes between locations for susceptibility to the fungus *M. diffusa* (PÉREZ-VEGA et al., 2013;

Received 10.06.23 Approved 05.04.24 Returned by the author 06.26.24
CR-2023-0541.R1
Editors: Alessandro Dal'Col Lúcio Leonardo Araujo

JIANG et al., 2019). Powdery mildew is difficult to control by conventional techniques as the fungus produces spores that are easily dispersed by the wind (NONOMURA et al., 2022).

Conventional control is carried out through preventive applications with fungicides; however, the indiscriminate application of chemicals can cause damage to the environment and resistance to fungicides (CORKLEY et al., 2022). In this context, there is a need for studies on the effectiveness of alternative products in controlling the disease (PERINA et al., 2013; GABARDO et al., 2022).

The sowing time and plant development phase are factors that may influence the response to alternative products application due to different inoculum pressure (BAJWA et al., 2017), which may result in different recommendations. Besides that, the association of alternative products to fungicides, reduces its applications, thus contributing to the rational use of pesticides and the insertion of alternative products in crop management, given the expressiveness of the areas cultivated with the oilseed.

This research evaluated the behavior of the soybean cultivar TMG 7062 IPRO, regarding the effect of foliar application alternative products isolated and associated with fungicide on the severity of powdery mildew in the field, as well as soybean yield in two sowing times, in 2016/2017 and 2017/2018 seasons in direct sowing system in straw.

MATERIALS AND METHODS

The experiments were installed in Ponta Grossa/PR (25º50'58" S and 50º09'30" W and altitude of 975 m), a humid subtropical climate, classified as CFb, according to Köppen climate classification. The average annual precipitation is approximately 1550 mm. The soil at the site is typical Eutrophic Tb HAPLIC CAMBISSOLO, clayey texture (EMBRAPA, 2006), (pH in water 5.9 (medium acidity), P (Mehlich 1): 2.2 mg.dm-3 (low), K: 70 mg.dm^{-3} (medium), S (monocalcium phosphate in acetic acid): 9.8 mg.dm^{-3} (good), Ca: 1.8 cmolc.dm^{-3} (medium), Mg: 1.3 cmolc.dm^{-3} (good), effective CTC (t): 4.3 cmolc.dm^{-3}(medium), M.O.: 3.6 dag.kg^{-1} (medium)).

The experiments were set up in two sowing times (October and December) in the 2016/2017 and 2017/2018 seasons, with the cultivar TMG 7062 IPRO, moderately resistant to powdery mildew, resistant to Asian soybean rust (*P. pachyrhizi*), semi-determined (TMG, 2023).

A row spacing of 0.45 m was used with 12 seeds per meter to obtain a density of 9 plants m^{-1} and a final population of 200,000 plants ha^{-1}. The consisted of foliar application of products: 1- control (water) (V4, V6, R1 and R5.1), 2- *Bacillus subtilis* lineage QST (V4, V6, R1 and R5.1) (3 L p.c. ha^{-1}), 3- *Bacillus subtilis* lineage QST (V4 and V6) (3 L p.c. ha^{-1}) associated with (azoxystrobin + benzovindiflupyr) (R1 and R5.1) (200 g p.c. ha^{-1}), 4- chitosan 1% (V4, V6, R1 and R5.1) (2 L p.c. ha^{-1}), 5- chitosan 1% (V4 and V6) (2 L p.c. ha^{-1}) associated with (azoxystrobin + benzovindiflupyr) (R1 and R5.1) (200 g p.c. ha^{-1}), 6- sulfur (S 26%) (V4, V6, R1 and R5.1) (2 L p.c. ha^{-1}), 7- sulfur (V4 and V6) (2 L p.c. ha^{-1}) associated with (azoxystrobin + benzovindiflupyr) (R1 and R5.1) (200 g p.c. ha^{-1}), 8- sodium hypochlorite (2.5%) (V4, V6, R1 and R5.1), 9- sodium hypochlorite (2.5%) (V4 and V6) associated with (azoxystrobin + benzovindiflupyr) (R1 and R5.1) (200 g p.c. ha^{-1}), 10-azoxystrobin + benzovindiflupyr (R1 and R5.1) (200 g p.c. ha^{-1}), 11- azoxystrobin + benzovindiflupyr (V6, R1 and R5.1) (200 g p.c. ha^{-1}). In all fungicide treatments, Nimbus® adjuvant (mineral oil, 0.5 v/v) was added. A randomized block design with four blocks and eleven treatments was used for each sowing season.

The field plots had dimensions of 4.5 x 4.0 m, totaling 18 m² of total area. The treatments used were applied via foliar use using a carbon dioxide cylinder with constant pressure (CO_2), equipped with a bar with simultaneous arrangement of four tips (XR 11002) spaced at 0.50 m and an application volume of 250 L.ha^{-1} for all treatments. Other cultural treatments were carried out according to the culture's requirements.

Powdery mildew severity assessments were carried out weekly during the crop cycle from the first symptoms. The percentage of leaf tissue attacked in the leaves of seven plants chosen at random, was estimated in the two central rows of each plot. Each plant was evaluated in its thirds (lower, middle and upper) and the average of the thirds was used to estimate the severity of the entire plant. These data made it possible to calculate the area under the disease progress curve (AUDPC) (SHANER & FINNEY, 1977).

At the end of the crop cycle, the plants in the useful area of each plot (9.0 m²) were harvested, weighed, threshed and their humidity measured. The production values obtained were converted to 13% humidity and the yield was estimated to kg ha^{-1}.

The data obtained were subjected to analysis of variance using the F test, the means, when significant, were compared using the Scott-Knott test at 5% probability. The analyzes were carried out using the R software, version 3.0.2 (R CORE TEAM, 2013).

RESULTS AND DISCUSSION

The first symptoms of powdery mildew occurred 35 days after emergence. Based on the severity assessments, the AUDPC 's were calculated (Table 1), the treatment with the lowest AUDPC in the first season was isolated sulfur, which presents, compared to the control, a reduction of 83.71% and 99.32% of AUDPC in the first and second sowing times, respectively. In the second season (Table 2), there was a reduction of 99.38 and 96.09% in the first and second sowing times, respectively.

Foliar application of all alternative products associated with the fungicide drastically reduced the severity of the fungus on soybean plants and consequently reduced AUDPC (Table 1 and Table 2). Sulfur, whether or not associated with the fungicide, provided lower disease severity and consequently lower AUDPC values.

In the first season (Table 1), the combination of sulfur and fungicide reduced AUDPC by 78.38 and 98.21% in the first and second sowing seasons, respectively. In the second season, there was a reduction of 99.33 and 95.92% in AUDPC in the first and second sowing seasons, respectively (Table 2).

The effect of the element sulfur (S) on fungi was discovered by William Forsyth in 1802, widely used in agriculture on fruit trees such as pear (*Pyrus communis* L.), acting to control powdery mildew. A few years later, Robertson in 1824 confirmed the

Table 1 - Area under the disease progress curve (AUDPC) of powdery mildew (*Microsphaera diffusa*) in the upper, middle and lower thirds and average in the entire plant, cultivar TMG 7062 IPRO, seasons 2016/2017 and 2017/2018, sowing in October and December. Ponta Grossa/PR.

Treatments	----------------AUDPC Sowing in October----------------				---------------AUDPC Sowing in December--------------			
	Lower third	Middle third	Upper third	Average for the whole plant	Lower third	Middle third	Upper third	Average for the whole plant
1 Witness (water)	2,237.61 a[*]	1,223.39 a	36.48 ns	1,165.83 a	2,364.90 a	1,166.47 a	265.45 a	1,265.61 a
2 *Bacillus subtilis*	1,744.32 c	809.08 c	28.05	860.49 c	2,343.14 a	1,039.57 a	198.40 b	1,193.70 a
3 *Bacillus subtilis* + (azoxistrobina + benzovindiflupir)	1,273.68 d	551.11 d	26.67	617.15 d	671.56 c	191.99 c	0.30 d	287.95 c
4 Chitosan	1,714.45 c	745.40 c	33.65	834.50 c	1,490.70 b	490.36 b	91.75 c	690.93 b
5 Chitosan + (azoxistrobina + benzovindiflupir)	997.63 e	351.14 e	26.47	458.41 e	368.20 d	79.97 c	0.30 d	149.49 d
6 Sulfur	392.47 g	156.62 f	20.33	189.81 f	11.57 e	10.97 c	3.00 d	8.52 d
7 Sulfur + (azoxistrobina + benzovindiflupir)	579.71 f	162.69 f	13.65	252.02 f	48.28 e	17.57 c	2.00 d	22.62 d
8 Sodium hypochlorite	1,959.87 b	960.58 b	35.24	988.56 b	2,149.52 a	1,246.09 a	265.38 a	1,220.33 a
9 Sodium hypochlorite + (azoxistrobina + benzovindiflupir)	1,357.48 d	526.83 d	24.82	636.38 d	806.68 c	202.36 c	1.31 d	336.78 c
10 Azoxistrobina + benzovindiflupir (R1 e R5.1)	1,275.61d	431.12 e	24.32	577.02 d	731.20 c	243.02 c	1.68 d	325.30 c
11 Azoxistrobina + benzovindiflupir (V6, R1 e R5.1)	695.64 f	267.41 f	9.47	324.17 f	334.23 d	92.10 c	1.10 d	142.47 d
C.V. (%)	11.99	27.62	68.65	11.66	20.23	35.89	42.30	21.00

Continued.
2016/20217 Season.
[*]Means followed by the same lowercase letter in the column do not differ from each other using the Scott-Knott test at 5% significance; ns= not significant; C.V.= coefficient of variation.

Table 2 - Area under the disease progress curve (AUDPC) of powdery mildew (*Microsphaera diffusa*) in the upper, middle and lower thirds and average in the entire plant, cultivar TMG 7062 IPRO, seasons 2016/2017 and 2017/2018, sowing in October and December. Ponta Grossa/PR.

Treatments	-----------------AUDPC Sowing in October----------------				--------------AUDPC Sowing in December-------------			
	Lower third	Middle third	Upper third	Average for the whole plant	Lower third	Middle third	Upper third	Average for the whole plant
1 Witness (water)	1,001.07 a*	578.99 a	11.07 a	530.37 a	2,172.56 a	882.52 a	45.21 a	1,033.43 a
2 *Bacillus subtilis*	825.32 a	414.12 b	8.76 a	416.07 b	1,936.89 a	727.66 a	41.95 a	902.17 a
3 *Bacillus subtilis* + (azoxistrobina + benzovindiflupir)	59.55 c	27.70 d	0.56 c	29.27 d	696.82 b	148.20 b	8.31 c	284.44 b
4 Chitosan	480.48 b	272.28 c	4.90 b	252.55 c	1,909.64 a	685.42 a	24.30 b	873.12 a
5 Chitosan + (azoxistrobina + benzovindiflupir)	9.52 c	2.07 d	0.11 c	3.90 d	754.22 b	159.13 b	4.06 c	305.80 b
6 Sulfur	5.57 c	4.05 d	0.10 c	3.24 d	68.14 c	46.30 b	6.68 c	40.37 c
7 Sulfur + (azoxistrobina + benzovindiflupir)	6.34 c	3.94 d	0.36 c	3.55 d	90.15 c	33.55 b	2.58 c	42.10 c
8 Sodium hypochlorite	920.28 a	515.22 a	9.90 a	481.80 a	1,957.93 a	738.44 a	44.26 a	913.54 a
9 Sodium hypochlorite + (azoxistrobina + benzovindiflupir)	105.41 c	47.52 d	0.20 c	51.01 d	858.56 b	248.41 b	8.12 c	371.70 b
10 Azoxistrobina + benzovindiflupir (R1 e R5.1)	127.96 c	57.99 d	0.15 c	62.02 d	875.83 b	232.81 b	7.56 c	372.06 b
11 Azoxistrobina + benzovindiflupir (V6, R1 e R5.1)	10.23 c	10.86 d	0.15 c	7.08 d	219.49 c	85.97 b	4.53 c	103.33 c
C.V. (%)	30.83	32.23	77.39	30.06	19.48	33.41	34.64	21.81

Conclusion.
2017/2018 Season.
*Means followed by the same lowercase letter in the column do not differ from each other using the Scott-Knott test at 5% significance; ns= not significant; C.V.= coefficient of variation.

efficiency in controlling powdery mildew on peach trees (*Sphaeroteca pannosa* ((Wallr.) Lév.)), further increasing its use (WANG et al., 2022).

Fungi can absorb inorganic S, including SO_4, as well as more reduced forms, and can assimilate organic S in the form of amino acids, sulfones, sulfonates, sulfones, sulfonamides and sulfamates (WANG et al., 2022). Due to its lipophilic characteristics, sulfur can penetrate the fungal wall and destabilize the metabolism reactions of pathogens, in addition to inducing resistance, as it is considered a natural reinforcement for plants against fungal pathogens (ZAMBOLIM et al., 2012).

In addition to sulfur, another alternative product that reduced AUDPC was chitosan (Table 1), in the first season, chitosan alone, compared to the control, reduced 28.42% of AUDPC at sowing in October. When the crop is sown in December, there was a reduction of 45.40%. In the second season (Table 2), there was a reduction of 52.38 and 15.51% in the first and second sowing seasons, respectively.

Chitosan has properties such as biodegradability, low toxicity, high bioactivity and antimicrobial activity (ARDEAN et al., 2021). This product shows promising results *in vitro*, on *Penicillium digitatum*, *Penicillium italicum*, *Botrytis cinerea*, *Alternaria alternata*, *Alternaria solani*, *Rhizopus stolonifer*, *Aspergillus niger* and *Colletotrichum gloeosporioides* (DAFERERA et al., 2003).

Regarding treatment with the bacteria *B. subtilis* (Table 1 and Table 2), there was a reduction in AUDPC in all experiments. According to CARBÓ et al. (2020), sprays with *B. subtilis* QST713 with concentrations of 2 and 4% were efficient in controlling powdery mildew on zucchini (*Sphaerotheca fugilinea*), corroborating the results of the present work that used a concentration of 2%.

The most efficient method of controlling powdery mildew is the use of resistant cultivars, however, even some cultivars considered resistant, when sown at the most favorable times for the occurrence of powdery mildew, become susceptible (PÉREZ-VEGA, 2013; BRASIL et al., 2018), making the application of fungicides necessary. Corroborating the data from the present work, which using a moderately resistant cultivar, required the use of other control methods, especially when sowing in December.

Late sowing resulted in higher AUDPC averages (Table 1). Late sowing or off-season sowing and winter cultivation are more favorable times for the occurrence of powdery mildew, because the fungus requires temperatures around 18-24 °C and low relative humidity for its development (JIANG et al., 2019), not developing at temperatures greater than 30 °C, and not germinating in the presence of a water film on the leaf surface (BEDENDO, 2011).

In the 2016/2017 season, the highest values for the disease's AUDPC were observed, in both sowing seasons, when compared to the 2017/2018 season (Table 1 and Table 2). This is due to the different meteorological conditions that occurred in each season, justifying the greater or lesser severity of the disease. In the 2017/2018 season, the highest volumes of precipitation occurred, which were well distributed, which was unfavorable for the disease, resulting in its lower severity.

In relation to the thirds of the plant evaluated, in the two seasons and sowing times, there was greater severity of the disease in the lower third, reflecting a greater AUDPC of the disease (Table 1 and Table 2). According to NASCIMENTO et al. (2018), in the lower part of the crop canopy, in addition to having higher relative humidity and lower temperatures, which favor the development of the fungus, during the application of fungicide there is a lower percentage of fungicide coverage on the leaves, due to the protective effect, canopy rain.

It was reported that the fungicide applied two or three times did not have an eradicating effect on the disease, despite the cultivar being moderately resistant to the pathogen (Table 1 and Table 2). Comparing the reduction in AUDPC in the treatment with two applications of the fungicide in the first season there was a reduction of 50.51 and 74.30%, in the second season the reduction was 88.30 and 64.00% when sowing in October and December, respectively.

When the fungicide was applied three times, in the first season there was a reduction of 72.19 and 88.74%, in the second season, there was a reduction of 98.66 and 90.00% in sowing in October and December, respectively (Table 1 and Table 2). Three applications of the product were more efficient than two in reducing the AUDPC of the disease.

Regarding the yield obtained, among the alternative treatments, isolated chitosan and sulfur stood out (Table 3). Isolated chitosan showed an increase of 17.86% in the first season and 12.75% in the second season in the second sowing season. Its association with the fungicide in the first season increased by 34.72% in the sowing in December and in the second season, 9.00% and 29.04% in the first and second sowing period, respectively. Although; chitosan alone reduced the AUDPC of the disease (Table 1 and Table 2), there was no difference in the yield obtained, a fact that only occurred when it was associated with the fungicide.

The application of sulfur alone and associated with the fungicide and the fungicide alone showed higher yield than the control (Table 3). These treatments provided the lowest AUDPC values (Table 1 and Table 2).

Resende et al. (2009), in a similar experiment, using the Vencedora cultivar, obtained productivity increase of 32.05% and 31.80% for sulfur doses of 2.0 and 3.0 L. ha^{-1}, respectively, comparing with the control. In the present experiment, the average gains in yield were 335.52 and 1,096 kg ha^{-1}, in the first and second sowing seasons, respectively for the sulfur treatment (2 L. ha^{-1}) associated with the fungicide. In the present experiment, the S content of the soil is suitable for the crop. The superior yield of the sulfur treatments was attributed to the reduction in powdery mildew AUDPC (Table 1 and Table 2).

Machado (2020), working with various foliar fertilizers, stated; that although, there was an increase in the foliar levels of some nutrients due to the application of the products, no positive results were observed in yield, possibly because the nutrient levels in the soil and the planting fertilizer were sufficient to meet the crop's requirements. Emphasizing that in the present research, the foliar application of sulfur avoided damage to yield due to its role in reducing the severity of diseases and not as a fertilizer.

Regarding the fungicide (Table 3), the treatment with two applications prevented

Table 3 - Yield (kg ha $^{-1}$) in October and December sowing times, cultivar TMG 7062 IPRO. Crops 2016/17 and 2017/18. Ponta Grossa/PR.

Treatments	---Yield---			
	---2016/2017---		---2017/2018---	
	October	December	October	December
1 Witness (water)	4,517.33 ns	3,552.30 a*	3,735.64 ns	2,953.45 a
2 *Bacillus subtilis*	4,692.60	3,506.98 a	3,878.70	3,243.11 b
3 *Bacillus subtilis* + (azoxistrobina + benzovindiflupir)	4,588.01	4,295.69 b	3,996.76	3,685.70 c
4 Chitosan	4,429.71	4,186.90 b	3,717.59	3,329.96 b
5 Chitosan + (azoxistrobina + benzovindiflupir)	4,461.15	4,785.75 b	4,096.29	3,811.17 c
6 Sulfur	4,634.65	4,504.84 b	3,826.85	3,432.40 b
7 Sulfur + (azoxistrobina + benzovindiflupir)	4,848.08	4,850.90 b	4,075.92	3,855.59 c
8 Sodium hypochlorite	4,313.80	3,651.43 a	3,784.72	2,903.96 a
9 Sodium hypochlorite + (azoxistrobina + benzovindiflupir)	4,972.46	4,502.66 b	3,781.48	3,629.94 c
10 Azoxistrobina + benzovindiflupir (R1 e R5.1)	4,559.74	4,312.59 b	3,759.72	3,757.91 c
11 Azoxistrobina + benzovindiflupir (V6, R1 e R5.1)	4,797.19	4,635.53 b	3,881.02	3,831.94 c
C.V. (%)	8.96	8.84	7.08	7.02

*Averages followed by the same lowercase letter in the column do not differ from each other using the Scott-Knott test at 5% significance; ns=not significant; C.V.= coefficient of variation.

damage compared to the control, in the first season of 0.90 and 21.40% and in the second season of 0.7 and 27.23% in the first and second season sowing, respectively. In the treatment with three applications of the fungicide, in the first season, 6.20 and 30.49% were obtained, and in the second season, 3.90 and 29.74% in the first and second sowing season, respectively. Control was greater in the second sowing season, due to the greater severity of the disease.

In the 2017/2018 season, yield was obtained with three applications of the fungicide of 3,881.02 and 3,831.94 kg ha^{-1}, and in the control of 3,735.64 and 2,953.45 kg ha^{-1}, in the first and second season of sowing, respectively (Table 3). Values close to those obtained in the present work were obtained by BÁRBARO-TORNIELI et al. (2018), in Araçatuba, São Paulo, using the same cultivar, but with sowing in November in the 2017/2018 season, the yield with fungicide was 3,581.48 kg ha^{-1} and 3,180.72 kg ha^{-1} in the control.

The average yields achieved with two and three applications of the fungicide in the 2016/2017 season were 4,678.47 and 4,474.06 kg ha^{-1} and in the 2017/2018 season, 3,820.37 and 3,794.93 kg ha^{-1} in the first and second sowing season, respectively (Table 3), these averages are higher than the average yield obtained in the State of Paraná of 3,731.00 kg ha^{-1} in the 2016/2017 season and 3,508.00 kg ha^{-1} for the 2017/ 2018 (CONAB, 2018).

In comparison, the yields obtained in the second sowing season were lower than the first season, probably due to factors such as sowing time and the greater inoculum pressure of the disease (BAJWA et al., 2017). In the first sowing season, there was no significant difference between treatments for yield, only in the second season (Table 3).

For this cultivar, based on experimental data, when sown in October, there is no need to apply products. According to TWIZEYIMANA et al. (2011), the effectiveness of the application and the product depends on the moment the disease is first detected and the intensity of its development.

According to the presentresearch, it was confirmed that the application of more than one group of fungicides (strobilurin and carboxamide) combined with sulfur (considered contact, eliminating and/or eradicating fungal structures on the surface of plants), improved the disease control (Table 1 and Table 2), in addition to presenting the highest yield averages (Table 3). In addition, this management strategy contributes to extending the useful life of the fungicide on the market.

The chemical groups strobilurin and carboxamide act on the fungus' mitochondrial respiration. Strobilurins act by inhibiting electron transport in mitochondrial complex 3, therefore, inhibiting fungal respiration and, consequently, the formation of ATP (AMARO et al., 2020). While carboxamides act on complex 2 of the electron transport chain, called the succinate dehydrogenase complex, resulting in the blocking of ATP production and the formation of intermediate molecules harmful to the cell (ATTANAYAKE et al., 2010).

Furthermore, these molecules are known to exert a positive physiological effect on the antioxidant metabolism of plants, contributing against both biotic and abiotic stress suffered (CORKLEY et al., 2022). It is recommended to use mixtures with at least two active ingredients with different actions in order to avoid the selection of fungus genotypes to chemical products (BRASIL et al., 2018).

The expansion of crop yield is closely linked to the development of applicable technologies that enable the competitive efficiency of soybeans. It is expected, due to the expressiveness of the areas cultivated with soybeans, that the savings in the number of fungicide applications will contribute to the rational use of pesticides in addition to extending the useful life of the products. In this way, the present research contributed to the insertion of alternative products for soybean management by producers in the region, in addition to confirming that when sowing in October there is no difference in yield, whatever the disease control method used in the TMG cultivar. 7062.

CONCLUSION

Sulfur, chitosan and *B. subtillis* alone reduced the severity of the disease. Alternative products, when associated with the fungicide (azoxystrobin + benzovindiflupyr), showed better performance than when applied alone. In the first sowing season (October) the severity of the disease was lower than in the second (December). Yield was affected by the products tested only in the second sowing season. Sulfur applied alone and other products associated with the fungicide (azoxystrobin + benzovindiflupyr) prevented damage to the crop. Sulfur alone and associated with the fungicide (azoxystrobin + benzovindiflupyr) was the most efficient in controlling powdery mildew.

ACKNOWLEDGEMENTS

Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Brasil – Finance Code 001.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript.

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