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ALTERNATIVE PRODUCTS TO CONTROL POWDERY MILDEW IN SOYBEANS CULTURE IN FIELD

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Abstract
The occurrence of powdery mildew (*Microsphaera diffusa*) in soybean (*Glycine max* L.) has increased in the last harvests. In order to study the efficiency of powdery mildew control due to the application of alternative products and conventional fungicide, trials were conducted in Ponta Grossa, PR, Brazil, during the 2013/2014 and 2014/2015 growing seasons. The design used was randomized blocks with four replications. The treatments for the experiments were: 1 - control; 2 - acibenzolar-S-methyl (Bion 500 WG®); 3 - calcium (Max Fruit®); 4 - Micronutrients: copper, manganese and zinc (Wert Plus®); 5 - Micronutrients: manganese, zinc and molybdenum (V6®); 6 - NK fertilizer (Hight Roots®); 7 - *Ascophyllum nodosum* (Acadian®) and 8 - fungicide (azoxystrobin + cyproconazole) (Priori XTRA®) with the addition of the adjuvant. Four applications of alternative products (phenological stages V3, V6, R1 and R5.1) and two of fungicide (phenological stages R1 and R5.1) were carried out. The parameters evaluated were powdery mildew severity and productivity. The severity data made it possible to calculate the area under the disease progress curve (AUDPG). Alternative products didn't reduce powdery mildew in the two harvests. The conventional fungicide treatment was the only one that controlled powdery mildew and didn't reduce the productivity in both experiments.

Keywords: Acibenzolar-S-methyl. Fungicide. *Glycine max* L. Micronutrients. *Microsphaera diffusa.*

1. Introduction

Soybean (*Glycine max* (L.) Merril) is the most important oilseed globally (Anderson et al. 2019). Due to its productive potential, protein source, chemical composition and nutritional value (USDA 2019). It is the main grain crop produced in Brazil, however the occurrence of diseases is a limiting factor for high yields (Battisti et al. 2018).

Among the diseases, powdery mildew caused by the fungus *Microsphaera diffusa* Cke. & Pk. stands out, since the 1996/97 harvest it has gained importance among the diseases that affect soybeans in the South and Midwest regions of Brazil, causing damage to yield estimated between 30% and 40% (Blum et al. 2016; Roese et al. 2017). The significant reduction in soybean yield is due to the reduction of the photosynthetically active area (Barcelos et al. 2018).

It is a mandatory parasite, which depends on the living host for its survival, growth and reproduction. The pathogen survival in tropical and subtropical regions occurs through mycelium and conidia produced by the fungus in plants of the host itself, in weeds or in voluntary plants (Godoy et al. 2016).

There are resistant cultivars (Leite et al. 2016), however, there is great variation in the genotype's reaction between locations for susceptibility to the fungus *M. diffusa*, due to the possibility of different physiological races among populations that occur in Brazil, then chemical control is the most used to control this disease (Pereira et al. 2012; De Almeida et al. 2017).

The indiscriminate use of pesticides can cause the selection of fungicide resistant strains of fungi, cause damage to the environment, lead to environmental imbalance, in addition to impacting the cost of crop production (Arruda et al. 2012; Tupich et al. 2017) and Brazil being the largest consumer of pesticide products in the world (Friedrich et al. 2018). In this context, the productive processes adopted in agriculture have been under pressure from society to produce food in a sustainable manner and without residues (Sentelhas et al. 2015; Pinela et al. 2017), which has led researchers to seek alternative measures for disease control. In addition to evaluating products trigger plant defense mechanisms, providing a further control alternative (Gabardo et al. 2020).

Thus, the present study aimed to evaluate the effect of foliar application of alternative products on the severity of powdery mildew in field and its influence on soybean crop productivity under no-tillage system in the cultivar BMX Potência RR in the 2013/2014 and 2014/2015 growing seasons.

2. Material and Methods

Two experiments under field conditions were conducted in Ponta Grossa - PR, Brazil, located at 25°13'latitude and 50°03'longitude and 900 m altitude, in the 2013/2014 and 2014/2015 growing seasons. The soil at the site is classified as a typical Eutrophic INCEPTISOL soil, clay texture (EMBRAPA 2006). The cultivation system adopted in the area is direct planting with straw. Monthly average temperatures, monthly total precipitation, and average humidity of the experimental area in the period were collected daily in an automated agrometeorological station located close to the experimental field.

The soybean cultivar used was BMX Potência RR, with sowing carried out under no-tillage system, on wheat straw, on 12/18/2013 and 12/16/2014, using 0.45 m spacing between rows with 15 seeds per meter to obtain density of 12 plants m^{-1} and final population of 250,000 plants ha^{-1}.

The experimental design adopted was randomized blocks, with 8 treatments and four replications, in plots measuring 6.0 x 4.0 m (24 m^2), with a useful area of 5.0 x 1.8 m (9.0 m^2). The treatments consisted of foliar application of the products: 1 - control (water); 2 - acibenzolar-S-methyl (Bion 500 WG®) (25 g c.p. ha^{-1}); 3 - calcium (Max Fruit®) (0.75 L c.p. ha^{-1}); 4 - micronutrients: copper, manganese and zinc (Wert Plus®) (0.75 L c.p. ha^{-1}); 5 - micronutrients: manganese, zinc and molybdenum (V6®) (0.75 L c.p. ha^{-1}); 6 - NK fertilizer (Hight Roots®) (0.75 L c.p. ha^{-1}); 7 - extract of the seaweed *Ascophyllum nodosum* (Acadian®) (2.0 L c.p. ha^{-1}) and 8 - azoxystrobin + cyproconazole (Priori XTRA®) (300 ml c.p. ha^{-1}) and adjuvant (0.5% v/v). The development of soybean culture was accompanied by the phenological scale proposed by Fehr and Caviness (1977), reviewed by Ritchie et al. (1997).

In the two experiments, 4 applications of alternative products were carried out in the phenological stages V3 (second developed trefoil), V6 (fifth developed trefoil), R1 (beginning of flowering) and R5.1 (grains noticeable to the touch (10% of grain)) and two applications of fungicide in the phenological stages R1 and R5.1. The applications were carried out using a knapsack sprayer with constant pressure (CO_2), equipped with a bar with simultaneous arrangement of four flat fan spray nozzles (XR 11002) spaced 0.50 m apart and pressure of 3 kg cm^{-2}. A flow rate of 250 L ha^{-1} was used for all treatments. Inoculation, basic fertilization and weed and pest control were carried out according to the needs of the crop.

Assessments of powdery mildew severity were performed weekly during culture cycle from the first symptoms. The percentage of leaf tissue attacked in the leaves of 10 plants random chosen was estimated in two lines of the useful area of the experimental plot. Each plant was evaluated in its thirds (lower, middle, and upper) and the thirds average used for the entire plant grade. Nine evaluations were carried out in the 2013/2014 growing season and seven evaluations in the 2014/2015 growing season of the severity of powdery mildew. The severity of powdery mildew was estimated with the aid of Mattiazzi (2003) diagrammatic scale. These data made it possible to calculate the area under the disease progress curve (AUDPG) (Shaner and Finney 1977).

To determine the productivity, all plants in the useful area of the experimental unit (9.0 m²) were cut and threshed with a Triton stationary beater. The volume of grains of each plot was weighed and its moisture was determined, being converted to 13% humidity, for the calculation of the final productivity (kg ha^{-1}).

The data obtained were subjected to analysis of variance by the *F* test and the significant means were grouped by the Scott-Knott test at 5% probability. The severity data in individual evaluations were transformed into $\arcsin\sqrt{(x + 0.5)/100}$. The analyzes were performed with aid of the statistical software SASM-Agri (Canteri et al. 2001).

3. Results and Discussion

Infection by the pathogen *M. diffusa* can occur at any stage of plant development, however, it is more visible at the beginning of flowering, the typical symptom of powdery mildew being a whitish to gray layer, consisting of mycelium and powdery conidia, which can cover the entire plant aerial part (Jun et al. 2012).

In the experiment, the first symptoms of powdery mildew were observed in V6 (37 DAE), remaining in the rest of the cultivar cycle (Figure 1 and Table 1) in both the first and second harvest. According to Xavier et al. (2015) this is because pathogens in the group of mildew present a highly evolved form of parasitism, as they depend on the living host for their survival, growth and reproduction, and can coexist throughout the life cycle with the plant.

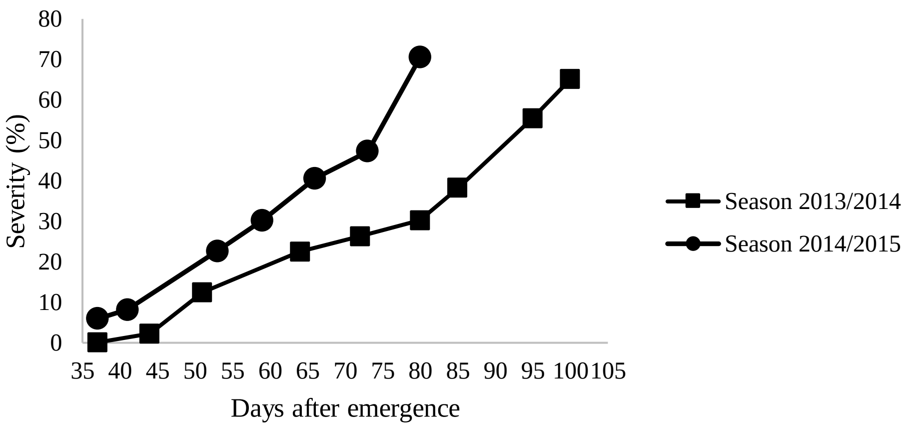

Figure 1. Severity (%) of powdery mildew (*Microsphaera diffusa*) obtained in the control in the 2013/2014 and 2014/2015 growing seasons, depending on the days after the emergence of soybean (*Glycine max* L.), cultivar BMX Potência RR. Ponta Grossa, PR.

The importance of each disease varies from year to year and from region to region depending on the climatic conditions of each growing season. Environmental conditions are fundamental in the development of powdery epidemics, with periods of drought, temperature between 20 and 25°C and relative humidity between 50 and 90%, favor the development of disease epidemics (Godoy et al. 2016).

There was a difference between the severities in the two growing seasons (Figure 1), this difference can be explained due to climatic conditions. In the first experiment (2013/2014 growing season) powdery mildew developed slowly from February. This can be explained by the average temperature of 19.5°C, relative humidity 87.4%. In the 2014/2015 growing season, powdery mildew developed rapidly in February, which can be explained by the average temperature of 20.7°C, relative humidity of 85.4%.

Late sowing (December) favored the occurrence of the disease, culminating in a maximum severity of 71.35% at 100 DAE in the first growing season, and in the second growing season a maximum severity of 73.50% at 80 DAE. The fungicide application showed a maximum control of 85.45% and 76.03%, in the first and second growing season respectively (Figure 1 and Table 1).

Silva et al. (2013) found control of powdery mildew in soybeans up to 90% using two applications of the fungicide pyraclostrobin + epoxiconazole, a mixture of strubirulin and triazole, similar to the product tested in the present experiment, in which the maximum control was lower (85.45% and 78.91%) indicating a possible loss of product efficiency.

In the present experiment, leaf fertilizers had no effect on powdery mildew (Table 1). However, Marschner and Marschner (2012) state that the nutritional status in which plants are found is directly related to the responses expressed by them. Nutritional imbalance, whether due to excess or lack of certain nutrients, favors the establishment of diseases and/or pests according to the nutrient(s) in imbalance in the plant tissue. Thus, due to their effect on growth pattern, morphology and anatomy, and particularly on the chemical composition of the plant, mineral nutrients can increase or decrease plant resistance to pests and diseases (Altieri and Nicholls, 2003; Macoski et al. 2021).

In the case of fungal diseases on the surfaces of roots and leaves, protection through balanced mineral nutrition would be the result: the formation of an efficient physical barrier, preventing the penetration of hyphae, through thick cuticle, lignification and/or accumulation of silicon in the layer of epidermal cells; better control of cytoplasmic membrane permeability, thus preventing the outflow of sugars and amino acids (on which pathogens feed) into the apoplast, or intercellular space; formation of phenolic compounds, with distinct fungistatic properties, in addition to biochemical mechanisms for inducing plant resistance against pathogens and pests (Shittu et al. 2021).

Table 1. Severity (%) of powdery mildew (*Microsphaera diffusa*) at 37 DAE (V6), 44 DAE (R1), 51 DAE (R2), 64 DAE (R5.1), 72 DAE (R5.2), 80 DAE (R5. 3), 85 DAE (R5.4), 95 DAE (R5.5) and 100 DAE (R6) in the 2013/2014 growing season and at 37 DAE (V7), 41 DAE (V8), 53 DAE (R2) 59 DAE (R3), 66 DAE (R5.1), 73 DAE (R5.2), 80 DAE (R5.3), in the 2014/2015 growing season, in different treatments performed with alternative products and fungicide on soybean (*Glycine max* L.), cultivar BMX Potência RR, average of the whole plant. Ponta Grossa, PR.

Treatment	2013/2014 growing season								
	Severity of powdery mildew (%)								
	37 DAE	44 DAE	51 DAE	64 DAE	72 DAE	80 DAE	85 DAE	95 DAE	100 DAE
1- Witness (water)	0.08ns*	2.19ns	12.48ns	22.46a	26.31a	30.22a	38.21a	55.40a	65.09a
2- Acibenzolar-S-methyl	0.06	1.83	9.03	18.77a	21.91a	24.82a	34.47a	46.94a	64.32a
3- Macronutrients: Ca	0.07	1.95	9.88	20.22a	27.23a	31.01a	37.89a	53.52a	69.93a
4- Micronutrients: Cu; Mn; Zn	0.08	0.96	8.49	18.11a	29.03a	24.59a	34.74a	50.98a	61.90a
5- Micronutrients: Mn; Zn; Mo	0.07	1.45	7.96	19.86a	24.36a	28.19a	35.32a	48.20a	62.65a
6- NK fertilizer	0.06	1.38	7.92	18.32a	26.92a	28.90a	35.73a	51.51a	64.95a
7- *Ascophyllum nodosum*	0.08	1.58	6.88	20.67a	24.73a	30.73a	36.74a	52.52a	71.35a
8- azoxystrobin + cyproconazole	0.08	1.06	7.96	12.44b	12.83b	5.64b	5.56b	13.79b	22.31b
C.V. (%)	38.90	33.53	25.83	15.44	13.99	14.34	11.15	10.95	10.86

Treatment	2014/2015 growing season						
	Severity of powdery mildew (%)						
	37 DAE	41 DAE	53 DAE	59 DAE	66 DAE	73 DAE	80 DAE
1- Witness (water)	5.90ns*	8.13ns	22.68ns	30.21a	40.58a	47.29a	70.54a
2- Acibenzolar-S-methyl	6.95	7.99	18.31	24.53a	34.45a	45.24a	73.50a
3- Macronutrients: Ca	5.45	7.50	24.28	24.82a	37.58a	45.85a	67.62a
4- Micronutrients: Cu; Mn; Zn	6.82	8.03	22.15	23.56a	38.27a	41.82a	66.71a
5- Micronutrients: Mn; Zn; Mo	6.01	7.62	23.43	23.09a	34.61a	44.25a	69.43a
6- NK fertilizer	6.42	6.07	23.15	24.46a	38.02a	45.68a	68.20a
7- *Ascophyllum nodosum*	5.72	7.74	24.34	29.45a	37.39a	43.45a	66.96a
8- azoxystrobin + cyproconazole	5.82	5.56	14.85	11.34b	8.56b	13.33b	17.62b
C.V. (%)	21.97	22.95	20.97	18.77	14.32	13.88	9.25

*Averages followed by the same lower case letter in the column do not differ by the Scott-Knott test at 5% significance; Original data, for analysis, the data were transformed into arc sen √ ((x + 0.5)) / 100 ns = not significant; DAE = days after emergency; C.V. = coefficient of variation.

In relation to ASM, a chemical activator of plant defense mechanisms, there was no difference in relation to the control, corroborating with Silva et al. (2013) who found a similar result using ASM in soybeans, where the inducer also did not differ from the witness in relation to powdery mildew control. Although there is no effect in relation to powdery mildew, this product is promising in the control of nematodes in soybean culture (Da Rocha et al. 2000).

Farmers have used chemical control frequently and there are several products registered for the control of this disease, among them we can mention those based on tebuconazole and azoxystrobin + cyproconazole. Application is recommended when the infection rate reaches 20% and make a maximum of 2 applications (ADAPAR 2020). Another control strategy is to consider the level of infection and stage of the soybean development when the infection level reaches 40 to 50% of the leaf area of the whole plant (Silva et al. 2007).

In the experiment, the first application of fungicide occurred in R1, when there was a low disease severity (2.19%, in the first growing season and approximately 10.00% of severity in the second growing season) and the second application of fungicide was carried out in R5. 1 (powdery mildew severity of 22.46% in the first harvest and 40.58% in the second growing season) (Table 1), contributing to disease severity reduction in both growing seasons.

Among the methods of disease control, genetic is the most efficient, and cultivars that are resistant to moderately resistant to fungus should be used. Another way to avoid losses by powdery mildew is not to sow susceptible cultivars in times more favorable to disease occurrence, such as late sowing or off-season and cultivation under irrigation in winter (Igarashi et al. 2014). The cultivar used is susceptible to powdery mildew and was sown late (in December), with the purpose of causing greater disease severity, which favored this in all thirds of the plant (Tables 1 and 2).

Table 2. Area below the disease progress curve (AUDPG) of powdery mildew (*Microsphaera diffusa*) in the lower, middle and upper thirds and average in the whole plant depending on the alternative and fungicide treatments performed on soybean (*Glycine max* L.), cultivar BMX Potência RR. Ponta Grossa, PR, 2013/2014 and 2014/2015 growing seasons.

Treatment	2013/2014 growing season			
	AUDPG Lower third	AUDPG Middle third	AUDPG Upper third	AUDPG Whole plant
1- Witness (water)	3065.76[a*]	1447.48[a]	437.33[a]	1650.19[a]
2- Acibenzolar-S-methyl	2787.22[a]	1053.33[a]	384.30[a]	1408.28[a]
3- Macronutrients: Ca	3109.11[a]	1282.57[a]	517.87[a]	1636.52[a]
4- Micronutrients: Cu; Mn; Zn	2876.86[a]	1139.39[a]	421.46[a]	1479.24[a]
5- Micronutrients: Mn; Zn; Mo	2830.61[a]	1120.24[a]	436.43[a]	1462.42[a]
6- NK fertilizer	2932.73[a]	1151.31[a]	486.55[a]	1523.53[a]
7- *Ascophyllum nodosum*	2792.77[a]	1358.58[a]	464.96[a]	1538.77[a]
8- azoxystrobin + cyproconazole	1074.65[b]	461.23[b]	105.85[b]	547.25[b]
C.V. (%)	26.87	31.67	33.81	19.27
Treatment	2014/2015 growing season			
	AUDPG Lower third	AUDPG Middle third	AUDPG Middle third	AUDPG Whole plant
1- Witness (water)	2276.26[a*]	1196.36[a]	404.56[a]	1292.39[a]
2- Acibenzolar-S-methyl	2180.36[a]	1071.53[a]	365.37[a]	1205.76[a]
3- Macronutrients: Ca	2305.22[a]	1141.48[a]	325.94[a]	1257.55[a]
4- Micronutrients: Cu; Mn; Zn	2159.89[a]	1082.33[a]	388.75[a]	1210.33[a]
5- Micronutrients: Mn; Zn; Mo	2217.03[a]	1139.62[a]	342.12[a]	1232.92[a]
6- NK fertilizer	2248.77[a]	1163.67[a]	306.75[a]	1239.73[a]
7- *Ascophyllum nodosum*	2224.35[a]	1266.99[a]	346.60[a]	1279.31[a]
8- azoxystrobin + cyproconazole	991.85[b]	328.41[b]	93.29[b]	471.18[b]
C.V. (%)	27.05	33.76	36.56	23.60

*Averages followed by the same lowercase letter in the column do not differ by the Scott-Knott test at 5% significance; C.V. – coefficient of variation.

This fungus is a mandatory parasite that develops throughout the aerial part of soybeans, such as leaves, stems, petioles, and pods (rarely observed), but it is more visible in leaves and stems (Mian et al. 2016). The most affected leaves were those of the lower third, and in this third, the values of AUDPG's were higher than the plant other thirds in both growing season (Table 2).

According to Igarashi et al. (2014) it is essential to prevent the entry of diseases that may eventually cause premature defoliation, especially those in the lower third of the plant, where the infectious process normally starts, that is, the entry of the fungus into the plant caused mainly after the closure of the lines, which hinders the penetration of products in the canopy of the culture, also favoring a greater number of hours of watering due to the formation of a microclimate favorable to the development of diseases.

Regarding AUDPGs, presented, only the treatment with fungicide differed from other treatments, showing a reduction in the value of AUDPG in the entire plant, in relation to the control of 66.84% and 63.54%, in 2013/2014 and 2014/2015 respectively (Table 2).

Soy powdery mildew is a sporadic and potentially important disease in soybean crops, which can cause damage of up to 40% in yield of susceptible cultivars (Yulia et al. 2017). These damages are due to the removal of nutrients from the cells by intracellular haustoria, the fungus interference in the process of photosynthesis by decreasing the amount of light on the leaves surface that can reduce more than half the photosynthetic activity, in addition to substantially reducing transpiration (Pereira et al. 2012).

In the 2013/2014 growing season (Table 3) the average control yield was 1,400.81 kg ha^{-1} and in the presence of alternative products the maximum productivity achieved was 1,900.90 kg ha^{-1} in the treatment with micronutrients (copper, manganese and zinc), the maximum reached in the presence of fungicide was 3,025.72 kg ha^{-1}. In relation to control, there was an increase of 53.70% in productivity, when fungicide was applied. The productivity achieved in the presence of fungicide is close to the average productivity obtained in the State of Paraná 2,950.00 kg ha^{-1} and in São Paulo 3,100.00 kg ha^{-1} in the 2013/2014 harvest (CONAB, 2020).

In the 2014/2015 growing season (Table 3) otherwise, the average control productivity was 1,308.28 kg ha^{-1} and in the presence of alternative products the maximum productivity achieved was 1,529.01 kg ha^{-1}, however the maximum achieved in the presence of fungicide was 2,303.46 kg ha^{-1}. The productivity obtained in the presence of the fungicide are below the average yield of the cultivar obtained in the State of Paraná of 3,043.00 kg ha^{-1} and in São Paulo 3,010.00 kg ha^{-1} in the 2014/2015 growing seasons (CONAB, 2020). When the fungicide was applied, it avoided 43.20% of damage to productivity compared to the control.

Table 3. Productivity (kg ha^{-1}) as a function of alternative and fungicide treatments performed on soybean (*Glycine max* L.), cultivar BMX Potência RR. Ponta Grossa, PR, 2013/2014 and 2014/2015 growing seasons.

Treatment	2013/2014 growing season	2014/2015 growing season
1- Witness (water)	1400.81^{b*}	1308.28^{b}
2- Acibenzolar-S-methyl	1716.89^{b}	1325.49^{b}
3- Macronutrients: Ca	1667.86^{b}	1334.22^{b}
4- Micronutrients: Cu; Mn; Zn	1900.90^{b}	1529.01^{b}
5- Micronutrients: Mn; Zn; Mo	1737.70^{b}	1307.56^{b}
6- NK fertilizer	1580.71^{b}	1310.18^{b}
7- *Ascophyllum nodosum*	1453.11^{b}	1278.73^{b}
8- azoxystrobin + cyproconazole	3025.72^{a}	2303.46^{a}
C.V. (%)	12.13	10.27

*Averages followed by the same lower-case letter in the column do not differ by the Scott-Knott test at 5% significance; C.V. – coefficient of variation.

Carvalho et al. (2013), obtained similar results in soybean culture, where productivity in the treatment with ASM, with 3 applications was 1160.90 kg ha^{-1}, not different from the control with 1195.90 kg ha^{-1} and the treatment with fungicide (azoxystrobin + cyproconazole) differed from the control presented the highest productivity of 2142.2 kg ha^{-1}.

Silva et al. (2013) reported that treatment with ASM (12.5 g c.p. ha^{-1}) associated with the fungicide (pyraclostrobin + epoxiconazol (66.5 + 25 g c.p. ha^{-1})) in soybean avoided damage to productivity. However, in this work, in relation to the isolated application of ASM (25 g c.p. ha^{-1}) at a higher dose, there were no differences in productivity (Table 3).

Work like Carvalho et al. (2013), confirm that only fungicide treatments prevented damage to productivity. Contradicting these authors, Silva et al. (2013), found greater productivity when they used ASM resistance inducer in soybean culture.

Dallagnol et al. (2006) using the cultivars IAS-5, Coodetec 201 (CD 201) and Fepagro RS-10 (RS 10), with foliar application of ASM (50 g c.p. ha^{-1}), observed that the cultivar IAS-5 and RS 10 showed no difference in relation to the productivity obtained. Only cultivar CD 201 showed a positive response of 9.2% in yield.

Comparing the work of Dallagnol et al (2006) with the present study, the data indicate different responses in relation to the cultivars, a fact that could explain the fact that the cultivar tested in this study does not respond to the application of the ASM.

There was no significant difference in productivity using micro and macronutrients (Table 3). According to Bhardwaj et al. (2014) each of the macronutrients and micronutrients plays at least one function within the plant and its deficiency or excess causes characteristic deficiency or toxicity symptoms. Influencing not only growth and productivity, but also increasing its resistance to pathogens (Altieri and Nicholls 2003).

Once incorporated into plant tissues, mineral nutrients become components or enzyme activators, or regulators of the degree of protoplasm hydration and, by extension, of the biological activity of proteins (Shittu et al. 2021). They can participate in the synthesis of compounds used in physical and or chemical barriers to microorganisms. Thus, the mineral nutrition of plants largely determines their resistance or susceptibility to various diseases (Carré-Missio et al. 2009).

The use of biofertilizers, for example, has been indicated for organic agriculture as a way of maintaining the nutritional balance of plants and making them less predisposed to the occurrence of pests and pathogens (Rodrigues et al. 2016; Gabardo et al. 2020).

Future experiments are necessary. Thus, associating the spraying of alternative products with fungicides, as Dallagnol et al. (2006), Santos et al. (2011) and Silva et al. (2013) demonstrated, can increase efficiency of fungicides when associated with inducers in disease control in soybean, wheat and soybean, respectively. This may contribute to a more satisfactory result, in addition to reducing the risk of selecting isolates resistant to fungicides and contributing to reducing the environmental impact.

4. Conclusions

In both growing seasons, the alternative products tested had no effect on control of powdery mildew of soybean.

The fungicide (azoxystrobin + cyproconazole) was the only one that controlled powdery mildew and prevented damage to productivity in both growing seasons.

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