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FUNGICIDES ALTERNATIVES FOR PRE-FLOWERING LINSEED

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ABSTRACT - Molecule rotation in the control of fungal diseases is essential to ensure sustainability and avoid the tolerance of pathogens to fungicides. Evidencing managements that promote greater efficiency in the control can contribute to increase the efficiency in the control of diseases.This work aims to reveal control alternatives for foliar diseases through different anti-fungal molecules applied in pre-flowering in the linseed crop. The experiment took place in the experimental area of Escola Fazenda, UNIJUÍ, located in the municipality of Augusto Pestana (RS). The experimental design used randomized blocks, with ten fungicide treatments in foliar application and three replications, totaling 30 experimental units. In the useful area of each experimental unit, the following characteristics were measured: plant height, plants per square meter, number of grains per plant, weight of grains per plant, grain yield, normalized green red difference index, green leaf index, spectral saturation index. The data obtained were submitted to descriptive analysis and to the assumptions of analysis of variance, such as homogeneity of residual variances by Bartlett's test and normality of errors by Shapiro Wilk. Afterwards, analysis of variance was carried out at 5% probability, with the significant variables, Tukey's test of multiple comparison of means was applied at the level of 5% of probability. In order to identify the tendency of association between the characters, Pearson's linear correlation was determined at 5% probability by t test. The active ingredient Pyraclostrobin + Fluxapyroxad can contribute favorably to the maintenance of floral units, capsules and grains per plant. The correct positioning of the use of the molecule is decisive and requires further studies in linseed culture.
Keywords: *Linum usitatissimum* L., linear correlation, pathogens.

ALTERNATIVAS DE FUNGICIDAS PARA A PRÉ-FLORAÇÃO DE LINHAÇA

RESUMO - A rotação de moléculas no controle de doenças fúngicas é essencial para garantir a sustentabilidade e evitar a tolerância dos patógenos aos fungicidas. Evidenciar manejos que promovem maior eficiência no controle podem contribuir para aumentar a eficiência no controle de doenças. Este trabalho tem como objetivo revelar alternativas de controle de doenças foliares por meio de diferentes moléculas antifúngicas aplicadas na pré-floração na cultura da linhaça. O experimento foi realizado na área experimental da Escola Fazenda, UNIJUÍ, localizada no município de Augusto Pestana (RS). O delineamento experimental utilizou blocos casualizados, com dez tratamentos fungicidas na aplicação foliar e três repetições, totalizando 30 unidades experimentais. Na área útil de cada unidade experimental foram medidas as seguintes características: altura da planta, plantas por metro quadrado, número de grãos por planta, peso de grãos por planta, rendimento de grãos, índice de diferença verde vermelho normalizado, índice de folha verde, índice de saturação espectral. Os dados obtidos foram submetidos à análise descritiva e aos pressupostos da análise de variância, como homogeneidade das variâncias residuais pelo teste de Bartlett e normalidade dos erros por Shapiro Wilk. Em seguida, foi realizada análise de variância a 5% de probabilidade, com as variáveis significativas, aplicou-se o teste de comparação múltipla de médias de Tukey ao nível de 5% de probabilidade. Para identificar a tendência de associação entre os caracteres, foi determinada a correlação linear de Pearson a 5% de probabilidade pelo teste t. O ingrediente ativo Piraclostrobina + Fluxapiroxade pode contribuir favoravelmente para a manutenção de unidades florais, cápsulas e grãos por planta. O correto posicionamento do uso da molécula é decisivo e requer mais estudos em cultura de linhaça.
Palavras-chave: *Linum usitatissimum* L., correlação linear, patógenos.

INTRODUCTION

Introduction of new species in current agricultural systems is fundamental for the diversification of products and foods, in addition to being a form of crop rotation. Among the new cultivation, alternatives adapted to the climate conditions in Rio Grande do Sul, linseed stands out, which has nutraceutical value and consequently high benefit to the grains (GOYAL et al., 2014). In Brazil, there is growing interest in the use of the grains of this oilseed in food and feed, however, the main destination is still in the industry, used as components of paints, varnishes, dyes, linoleum and biodiesel (OLIVEIRA et al., 2012).

According to FAO (2020), world production in a decade went from 1.81 million tons to 3.37 million tons, in

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an area of 3.50 million hectares in 2020, that is, a growth of 72.5% in cultivated area. Linseed shows low cost compared to other winter crops. According to INTA (2014), the low production cost and versatility of linseed can replace wheat in succession with soybean, making the crop a very interesting winter alternative for different agricultural areas in Argentina.

The rusticity of linseed guarantees greater sustainability to agricultural production, with few phytosanitary managements carried out during its cultivation. Among the factors that can influence linseed grain yield, we can mention the sowing process, the adequate choice of plant arrangement and sowing time, which can reflect on the phenotypic manifestation of beneficial characteristics for the interception and use of incident solar radiation (TOMASSONI et al., 2013). This relates to the occurrence and severity of foliar, root and secondary diseases to the crop.

Among the diseases are rust (*Melampsora lini*), anthracnose (*Colletotrichum lini*), fusarium leaf spot *(Fusarium oxysporum* sp. *lini*) and the astonishment caused by the pathogen *Septoria linicola*, commonly seen in western Canada (RASHID et al., 2016), reduces the quality and quantity of grains per plant by up to 70% (RASHID, 2001). The initial symptoms of stun are small dark brown to black lesions on the lower leaves of plants, occurring in the early stages to maturity. Precipitation and wind spread the inoculum to leaves and stems on adjacent plants. In high infestations, dark brown to black bands appear on the stems after flowering (RASHID, 2015). Genetic improvement and the adjustment of practices and managements becomes an alternative to reduce the data on these pathogens (HELLER et al., 2015). Due to the lack of information about this crop, this work aims to reveal control alternatives for foliar diseases through different anti-fungal molecules applied in pre-flowering in the linseed crop.

MATERIALS AND METHODS

The experiment took place in the experimental area of Escola Fazenda, Universidade Regional do Noroeste do Estado do Rio Grande do Sul (UNIJUÍ), located in the municipality of Augusto Pestana - RS, at 28° 26' 20" S and 54° 00' 23' 'W, at an altitude of approximately 301 m. The soil classification of the experimental area is Typical Dystroferic Red Latosol and the characterizations of the climate by Köppen as *Cfa* (humid subtropical). The experimental design used randomized blocks, with ten fungicide treatments in foliar application (Table 1) and three replications, totaling 30 experimental units.

TABLE 1 - Managements used in pre-flowering in linseed crop.

Managements	Product Mix/Doses	Application Time	VS¹
I	Absence	NA²	NA²
II	0,35 L ha Orkestra (Pyraclostrobin + Fluxapyroxad)	122 DAS³	100 L ha
III	0,75 L ha Nativo (Trifloxystrobin + Tebuconazole)	122 DAS³	100 L ha
IV	0,35 L ha Abacus (Pyraclostrobin + Epoxiconazole)	122 DAS³	100 L ha
V	0,3 L ha Aproach Prime (Picoxystrobin + Cyproconazole)	122 DAS³	100 L ha
VI	0,75 L ha Propiconazole	122 DAS³	100 L ha
VII	0,72 L ha Fusão (Metominostrobin + Tebuconazole)	122 DAS³	100 L ha
VIII	0,75 L ha Opera Ultra (Pyraclostrobin + Metconazole)	122 DAS³	100 L ha
IX	0,75 L ha Versatilis (Phenpropimorph)	122 DAS³	100 L ha
X	2 kg ha Triziman (Azoxystrobin + Cyproconazole + Mancozeb)	122 DAS³	100 L ha

VS¹ = volume of spray (L ha^{-1}), NA² = not applicable, DAS³ = days after sowing.

The experimental units were 3 m wide and 5-m long, sown in the first half of April 2021 and harvested on September 10th, 2021, with lines spaced by 0.18 m, with a seeding density of 50 kg ha^{-1} of seeds, base fertilization of 300 kg ha^{-1} and 100 kg ha^{-1} of nitrogen (N) 40 days after sowing. The management of insect pests and invasive plants took place in a preventive manner, in order to minimize the biotic effects on the results of the experiment. In the useful area of each experimental unit, the following characteristics were measured: plant height (PH, cm), plants per square meter (PPSM, units), number of grains per plant (NGP), weight of grains per plant (WGPP, g), grain yield (GY, kg ha^{-1}), normalized green red difference index (NGRDI), green leaf index (GLI), spectral saturation index (SI).

The data obtained were submitted to descriptive analysis and to the assumptions of analysis of variance, such as homogeneity of residual variances by Bartlett's test and normality of errors by Shapiro Wilk. Afterwards, analysis of variance was carried out at 5% probability, with the significant variables, Tukey's test of multiple comparison of means was applied at the level of 5% of probability. In order to identify the tendency of association between the characters, Pearson's linear correlation was determined at 5% probability by t test. The meteorological information medium temperature (Tmed, °C), minimum (Tmin, °C) and maximum air temperature (Tmax, °C), precipitation (Prec, mm), relative humidity (RH, g kg^{-1}) and incident radiation (Rad, MJ m^{-2} dia^{-1}) were expressed in order to better understand the results obtained (NASA POWER, 2021). For the preparation of the statistical analysis, the packages Exp.Des.pt, metan and ggplot2 were used through the Software R (R Core Team, 2021).

RESULTS AND DISCUSSION

In the periods of emergence and vegetative development of linseed (Figure 1), between April and June, the magnitudes of relative humidity and air temperature were high, conditions combined with plant density, favor the development of diseases in the crop, especially anthracnose, as the inoculum source is present along with seeds, crop residues and alternative hosts (MADALOSSO et al., 2022). The relative humidity of the air during the whole linseed cultivation was high, being favorable for the dissemination of spores of *Septoria linicola*, which coincides with Sackston (1970), where he observed that spores are more frequently spread by humid air, instead of dry air.

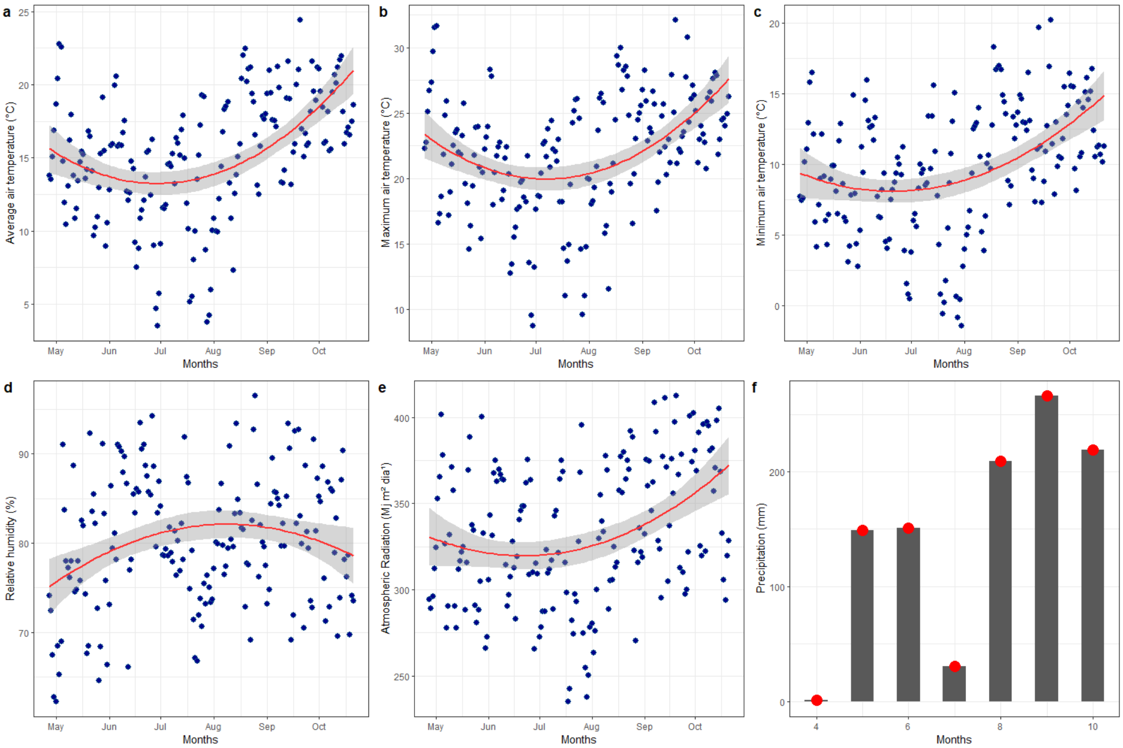

FIGURE 1 - Meteorological data of medium (Tmed, °C), minimum (Tmin, °C) and maximum air temperature (Tmax, °C), precipitation (Prec, mm), relative humidity (RH, g kg^{-1}) and incident radiation (Rad, MJ m^{-2} day^{-1}), expressed during linseed cultivation.

Analysis of variance (Table 2) revealed significance at 5% probability by the F test for the variable green leaf index (GLI). Linseed is susceptible to a number of diseases that affect grain yield and quality, such as pasmo, fusarium, rust, powdery mildew, seedling blight, root rot, sclerotinia and aster yellow (RASHID, 2001). That is, the low disease pressure contributes to the green leaf index in the crop and consequently maximized the photosynthetic activity of the plant. The coefficient of variation was low for all measured variables, demonstrating the effectiveness of the results.

TABLE 2 - Analysis of variance for plant height (PH), number of grains per plant (NGPP), normalized green red difference index (NGRDI), green leaf index (GLI), plant per square meter (PPSM), weight of grains per plant (WGPP), grain yield (GY).

SV[1]	DF[2]	MS[3]						
		PH	NGPP	NGRDI	GLI	PPSM	WGPP	GY
Treatments	9	108.904	492.82	0.000075	0.00016*	3717.0	0.001098	58361
Block	2	77.163	1255.06	0.00016	0.00011	2957.5	0.004821	244956
Residue	18	83.526	464.10	0.000054	0.000051	5502.9	0.002819	79123
Total	29							
CV(%)		4.96%	24,70%	11.36%	10.28%	15.26%	26.54%	26.20%

SV[1] = source of variation, DF[2] = degrees of freedom, MS[3] = mean square. *Significant at 5% probability by the F test.

Plant height presents itself as an extremely important character in linseed cultivation, canopies with plants smaller than 80 cm are sought, because when exceeding these limits some problems are evidenced, such as lodging, minimization of basal ramifications and part area and thinner stems. These morphological changes can be observed through the seasonality of nitrogen applications in the crop, as well as the adjustment of plants per unit area. In this study, plants with 58.2 cm were obtained, these being within the intended agronomic ideotype, when considering the analysis of variance, it is determined that there was no variation of this character due to the treatment performed.

The magnitude of plants per unit of area is based on the attributes of the physiological quality of the seeds used, recommended seed density according to the genotype and plant arrangement previously established by the producer. These attributes anchor the yield component plants per square meter (PPSM), which again does not show variability at the level of treatment, a fact that was expected due to the excellent initial establishment of the canopy and the diseases that affected the leaf area of the plants did not reflect in losses. of plants in the experimental unit. Under these conditions, 486 viable plants per square meter were obtained, which results in 4.86 million plants per hectare, considering a well-established canopy.

The number of reproductive units per plant is dependent on the magnitude and time of flowering, as well as on the viability of the formed capsules. It is a challenge for the linseed crop to maintain or increase the number of grains per plant (NGPP) because this character depends on the good nutrition of plants with phosphorus, boron, molybdenum and zinc, needs that are addressed by basic fertilization, however the lower seasonality of rainfall and the severity of foliar diseases tend to positively influence this attribute. It is observed that the analysis of variance did not reveal significance for this variable, however, the descriptive analysis reveals that there are treatments such as *Pyraclostrobin + Fluxapyroxad* that showed up to 114 grains per plant and, regardless of the management used in pre-flowering, it obtained an average tendency of 87 grains (Table 3).

TABLE 3 - Joint means test for plant height (PH), number of grains per plant (NGPP), normalized green red difference index (NGRDI), green leaf index (GLI), plant per square meter (PPSM), weight of grain per plant (WGPP), grain yield (GY).

Managements	PH	NGPP	NGRDI	GLI	PPSM	WGPP	GY
Pyraclostrobin + Epoxiconazole	56.47a*	78.33a	0.07 a	0.07ab	510.00a	0.17a	1036.55a
Picoxystrobin + Cyproconazole	56.07a	95.33a	0.05 a	0.06ab	533.33a	0.21a	1264.99a
Metominostrobin + Tebuconazol	57.80a	82.00a	0.06 a	0.07ab	470.00a	0.19a	1009.41a
Trifloxystrobin + Tebuconazole	58.13a	87.30a	0.05a	0.05b	535.00a	0.20a	1221.07a
Pyraclostrobin + Metconazole	56.20a	75.70a	0.06a	0.07ab	446.67a	0.19a	931.11a
Pyraclostrobin Fluxapyroxad	61.27a	114.30a	0.06a	0.06ab	475.00a	0.24a	1284.10a
Propiconazole	61.53a	100.38a	0.06a	0.07ab	461.67a	0.21a	1082.67a
Azoxystrobin + Cyproconazole + Mancozeb	58.80a	72.47a	0.06a	0.06ab	520.00a	0.17a	1026.27a
Phenproprimorf	57.90a	86.18a	0.06a	0.06ab	465.00a	0.19a	1008.05a
Check	58.26a	80.27a	0.06a	0.08a	443.33a	0.18a	873.66a

*Means followed by the same lowercase letter in the column do not differ statistically from Tukey, at the 5% probability level.

Weight of grain per plant is based on the dynamics of assimilate partitioning, which concerns the number of total capsules, viable capsules, position of the capsules in the plant and number of grains per capsule. Plants that meet the agronomic ideotype tend to maximize grains per plant, but it is understood that these must show viability and acceptable weight. Linseed plants submitted to pre-flowering fungicide managements do not differ statistically, but center their results around 0.2 grams of grains per plant, but promising preliminary results can be expressed in the sequential use of *Pyraclostrobin + Fluxapyroxad* directed in pre- and post-flowering.

The yield of grains per hectare is constructed by the interrelationships of the number of plants per unit of area, weight of grains per plant and average weight of grains, these attributes are complex and must be considered essential for the maximization of the crop yield. It is evident that in this study an average of 1074 kg ha^{-1} of grains corrected to 8% moisture was obtained, it is revealed that the optimal expectation of the culture is 1500 kg ha^{-1} of grains, statistically there was no significance, but it is revealed that the use of *Pyraclostrobin + Fluxapyroxad* can potentiate this characteristic, resulting in 1284 kg ha^{-1}. The meticulous adjustment of cultural practices and management may help in future works in the increase of 216 kg ha^{-1} so that the expectation of the culture can be met. It is known that the economic return of grains varies between four to R$ 5.00 kg^{-1} of grain produced, under these conditions the gross economic return was R$ 6,420 reais ($ 1.329) and net of R$ 4,300 reais ($ 890) considering a production cost of 33%.

The phenomenical indices of normalized green and red spectrum difference (NGRDI), green leaf index (GLI) and spectral saturation index (SI) has the purpose of expressing the health of plants and their contribution to the constitution of chlorophyll and closure of the canopy. Under these conditions, greater effects were observed together in managements with the use of fungicides, as well as in their absence. This reveals that all experimental units have a high sanity in the pre-flowering period, where it is indicated that new measurements should be carried out during and after flowering, followed by grain filling.

According to Pearson's linear correlation, which measures the degree of association between variables (Figure 2). A positive, significant correlation of moderate magnitude was observed between incident radiation (RAD_O_L) and green leaf index (GLI) (0.65), that is, the greater the incidence of radiation, the greater the phosynthetic activity of plants, for mendium temperature (Tmed), minimum temperature (Tmin) showed a strong positive correlation for green leaf index (GLI) with values of 0.73 and 0.71, respectively, since the highest production is concentrated in the southern region of the country due to to the subtropical climate, providing adequate thermal conditions for plants that need mild temperatures for their development (BASSEGIO et al., 2012). The mean temperature correlated significantly positive with moderate magnitude (0.66) spectral slope saturation (SI), that is, the lower the vegetation cover on the ground, the higher the medium temperature (Tmed) of the canopy tends to be.

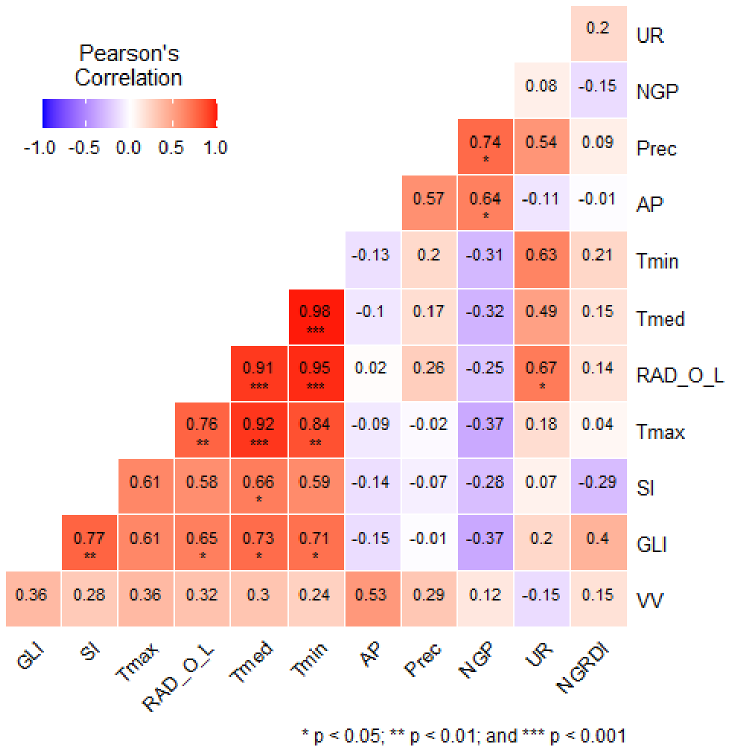

FIGURE 2 - Pearson's linear correlation for meteorological variables in relation to agronomic characteristics of linseed. Green leaf index (GLI), spectral slope saturation index (SI), maximum temperature (Tmax), incident radiation (RAD_O_L), medium temperature (Tmed), minimum temperature (Tmin), plant height (PH), precipitation (Prec), number of grains per plant (NGPP), relative humidity (RH), normalized green red difference index (NGRDI).

Regarding maximum temperature (Tmax), strong positive correlations were identified for incident radiation (RAD_O_L), minimum temperature (Tmin) and medium temperature (Tmed). Very strong positive significant correlations occurred for incident radiation and medium and minimum temperature (0.91) and (0.95). Very strong significant correlation occurred between medium temperature (Tmed) and minimum temperature (Tmin).

The variable number of grains per plant (NGPP) was significantly positively correlated with moderate and strong magnitude with plant height (PH) and precipitation (Prec), according to Stanck et al. (2017), edaphoclimatic adaptations are essential, influencing plant growth, development and productivity. According to Stanck et al. (2017) and Floss (1983), this culture requires mild temperatures for flowering to occur, since when these do not occur, they end up delaying flowering and prolonging the vegetative period, being considered a culture of long days and water demand. between 400 and 750 mm.

The incidence and development of pathogens in plants is associated with the ideal conditions for their development. Unfavorable conditions imply reduced severity and damage to crops. In this case, the meteorological conditions during linseed cultivation were not favorable for the development of diseases, so the fungicides did not express differences in the crop's grain yield. New studies should be developed in more crop seasons, as well as in other regions to understand the dynamics of fungicide efficiency in scenarios with high incidence of pathogens.

CONCLUSIONS

The active ingredient Pyraclostrobin + Fluxapyroxad can contribute favorably to the maintenance of floral units, capsules and grains per plant.

The correct positioning of the use of the molecule is decisive and requires further studies in linseed culture.

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