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Organic cultivation of *Allium fistulosum* under concentrations of Bordeaux mixture

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Abstract

Allium fistulosum L., belonging to the botanical family Alliaceae, is one of the most produced and commercialized vegetables in the world. In this scenario, this study aimed to evaluate the control of anthracnose in chives subjected to organic cultivation with different concentrations of Bordeaux mixture and its effects on crop yield. The experiment was conducted in elevated soil beds 10-cm high. Seedlings of the chive cultivar 'Todo Ano' were produced from plants previously cultivated in the site. Cultivation was carried out under full sunlight, and irrigation was performed by automatic sprinklers with a daily volume of 6 mm. The experiment was in randomized blocks, with 10 treatments in a 2x5 factorial arrangement. Four concentrations of Bordeaux mixture (0.5%; 1.0%; 1.5%; 2.0%) plus one control (water) were used. The second factor evaluated was the weekly and fortnightly application period. Data on the Total Fresh Mass (MFT), Commercial Fresh Mass (MFC), Sick Fresh Mass (MFR), Number of Commercial Leaves (NFC), Number of Sick Leaves (NFR), Commercial Dry Mass (MSC), and Yield (PTV) were collected. No statistically significant interactions were observed for anthracnose control and chive yield. However, in the 4th week of evaluation, differences were observed between the application periods, with the 2.0% concentration and weekly application performing better than the other treatments. The other evaluations did not result in significant statistical interactions between the variables analyzed. The application of Bordeaux mixture has no effects on the control of anthracnose and on the yield of chives.

Keywords: Amazon Rainforest, Chives, Yield

Introduction

The species *Allium fistulosum* L., also known as chives, belongs to the botanical family Alliaceae. Native to Siberia, this species is one of the most produced and marketed vegetables in the world and is widely cultivated in Brazil, especially in the North and Northeast regions, benefiting from characteristics such as easy management and an important social role in small family farming areas (Silva et al., 2018).

A. fistulosum has cylindrical and fistulous leaves, with tillering and tussock formation. The crop can be produced throughout the year under the edaphoclimatic conditions of Brazil, adapting to a wide temperature range (Silva et al., 2022). It usually develops well under mild climate conditions (from 8 °C to 22 °C). However, its establishment and use has been recognized in tropical regions, where cultivars resistant to high temperatures are used in association with intercropping with other vegetables (Pinheiro et al., 2020).

However, despite its easy cultivation, several diseases can affect the yield of chives, with leaf anthracnose constituting one of the commonest problems, caused by fungi of the genus *Colletotrichum*. This disease compromises the quality of the product, causing losses that can reach the entire harvested volume (Oliveira et al., 2019). The main symptoms of anthracnose in chives include circular and depressed lesions characterized as light brown halos. These lesions are gradually fused, forming a large necrotic area and resulting in leaf death (Souza et al., 2018).

Controlling anthracnose in chives has been an enormous challenge, especially in the Amazon Region, characterized by having a humid tropical climate, favorable for the establishment of this pathogen. For being a short-cycle plant whose cultivation occurs on a small scale, it is still not possible to find fungicides

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registered with the Ministry of Agriculture, Livestock, and Supply of Brazil (MAPA) for the control of anthracnose in chives (Agrofit, 2022; Araújo et al., 2012). In this scenario, alternative cultivation methods that promote higher yields and attenuate the incidence of diseases such as anthracnose are of paramount importance.

The Bordeaux mixture is an agricultural input widely used in organic vegetable gardens and orchards in Brazil. Several studies have already reported its efficiency in controlling many diseases caused by fungi, e.g., mildew, rust, late blight, early blight, cercosporiosis, anthracnose, leaf spots, plant rot, and bacterioses. This mixture has also been reported to have a repellent effect against insects such as green leafhoppers, mealybugs, thrips, and aphids. The Bordeaux mixture is usual in organic agriculture due to the low toxicity of its components, e.g., copper sulfate and lime, in addition to contributing to nutrient balance in plants by providing calcium and copper (Silva et al., 2017).

From this perspective, this study aimed to evaluate anthracnose in chive plants subjected to organic cultivation with different concentrations of Bordeaux mixture and its effects on the crop's yield.

Material and Methods

The experiment was conducted at the Seridó Ecological Station in Rio Branco – AC, located on Branch José Ruy Lino, Highway Km 1.7, on the left bank of the Porto Acre road, Km 5, at the geographic coordinates 9°53'16'' S and 67°49'11'' W, at an elevation of 150 m above sea level. The experiment lasted from September 7 to October 21, 2021. The regional climate is classified as *Am*, i.e., a hot and humid climate, according to the Köppen classification (1918). The mean temperature recorded in the region was 25.4°C, and the relative humidity was 88.4% (Inmet, 2021).

The experiment was set up in plant beds measuring 1 m x 6 m, with a height of 10 cm and covered with polypropylene plastic, in which circular holes were opened where each seedling was transplanted. The purpose of the plastic was to prevent the growth of weeds and to maintain soil moisture. The plant beds were raised using hoes, and organic compost was incorporated at the dose of 15 ton/ha, aiming to provide the nutrients necessary to improve the physical and chemical soil properties.

The seedlings of the chive cultivar 'Todo Ano' were produced asexually, as this cultivar can be grown at any time of the year. The tillers used were selected after the harvest of commercial leaves, with the roots being trimmed with pruning shears before planting. The chive seedlings were then immersed in biofertilizer for 10 minutes to provide the initial nutrient input necessary to stimulate plant resistance against diseases (fungistatic/bacteriostatic effect). The biofertilizer was based on sugarcane bagasse, wheat bran, Napier grass, castor bean cake, *Gliricidia* bran, and inoculants (EM4, kefir, and water). After the plant beds were prepared with the plastic cover, two seedlings were planted per hole. The experimental design adopted was in randomized blocks, with 30 plants per treatment in 3 blocks and 10 treatments. The plant spacing adopted was 25 x 15 cm between rows and plants. The plants were grown under full sunlight, and irrigation was performed automatically using sprinklers installed 1 m above the bends, with a daily irrigation depth of 6 mm.

Four Bordeaux mixture concentrations and one control were used in the experiment, as seen in **Table 1**. The applications were performed weekly and fortnightly, in a 2x5 factorial arrangement.

The planting area has a history of anthracnose, with other nearby cultivation areas showing symptoms of the disease. Therefore, throughout the experiment, it was possible to observed anthracnose signs in healthy seedlings subjected to treatment with the Bordeaux mixture at different concentrations and application periods.

For the production of the Bordeaux mixture, 200 g of copper sulfate was initially added to 5 L of water; separately, 200 g of quicklime was added to 5 L of water; then, the two solutions were mixed, thus obtaining a final volume of 10 L of mixture at the concentration of 2%. Subsequently, the mixture was filtered through a cloth to avoid clogging the spraying nozzle. The mixture was diluted into different concentrations to obtain the concentration of each treatment. A backpack sprayer was used to apply the treatments. After spraying the control (water), a 500-mL measuring cup was used to prepare the dilutions, from the lowest to the highest concentration, following the application order. For the concentration of 0.5%, 1 measuring cup of Bordeaux mixture was mixed with 3 cups of water; for 1.0%, 2 cups of Bordeaux mixture were

Table 1 – Identification of the treatments used in this study

TREATMENT	APPLICATION	CONCENTRATION
T1	Weekly	0.0%
T2	Weekly	0.5%
T3	Weekly	1.0%
T4	Weekly	1.5%
T5	Weekly	2.0%
T6	Fortnightly	0.0%
T7	Fortnightly	0.5%
T8	Fortnightly	1.0%
T9	Fortnightly	1.5%
T10	Fortnightly	2.0%

homogenized with 2 cups of water; for 1.5%, 3 cups of Bordeaux mixture were homogenized with 1 cup of water; finally, the 2.0% concentration did not require dilution.

The evaluations began 35 days after planting by analyzing commercial and sick leaves. The leaves were manually collected along with their lower part and data on the following variables were collected: Total Fresh Mass (MFT), obtained by weighing all leaves of the plot in an analytical balance, Commercial Fresh Mass (MFC), determined by weighing only the commercial laves; Sick Fresh Mass (MFR), determined by weighing the sick leaves; Number of Commercial Leaves (NFC) and Number of Sick Leaves (NFR), determined by counting; Commercial Dry Mass (MSC), determined by oven-drying to constant weight at 65 °C; and Yield (PTV). The yield was calculated based on the Commercial Fresh Mass/85g/m^2 (equivalent to the number of tussocks per m^2), with 85 g being the equivalent to one chive bunch. The evaluations were performed weekly for five weeks, totaling 10 weekly applications and 5 fortnightly applications.

The data were checked for the presence of outliers by Grubbs' test, verification of normality of errors by the Shapiro Wilk test, and verification of homogeneity of variances by Cochran's test, followed by analysis of variance and regression analysis. The statistical analyses were performed using the software R and the technological aid package ExpDes.pt. (Ferreira et al., 2014).

Results and Discussion

There were no significant statistical interactions between the concentrations of 0.0% (control), 0.5%, 1.0%, 1.5%, and 2.0% of Bordeaux mixtures applied. However, significant interactions were observed between the application periods and concentrations only in the 4th week of evaluations after 35 days of planting (**Table 2**). The other evaluations (1st, 2nd, 3rd, and 5th weeks) did not show significant statistical interactions between the variables analyzed.

In the 4th week, when analyzing the frequency of application of Bordeaux mixture (weekly or fortnightly) for the Total Fresh Mass (at the concentration of 2.0%), the weekly application was more effective in promoting a higher yield of *A. fistulosum* (**Figure 1**).

With regard to the Commercial Fresh Mass, there was a significant difference in yield when related to the application times with the weekly application of Bordeaux mixture being most effective in yield at the concentrations of 1.5 and 2.0%, whereas the fortnightly applications were most effective at 0.5 and 1.0% (**Figure 2**).

The positive results observed in the fourth week

Table 2 – Mean production of *A. fistulosum* under different concentrations of Bordeaux mixture in the 4th week, 35 after days of planting. Rio Branco – AC, 2022

Application	Concentrations (%)				
	0.0	0.5	1.0	1.5	2.0
	Total fresh mass (g)				
Weekly	300.67	229.67	252.33	286.33	338.00a
Fortnightly	341.67	292.00	292.33	227.33	245.67b
	Commercial fresh mass (g)				
Weekly	264.00	190.33b	226.67b	243.67a	300.33a
Fortnightly	297.33	252.00a	280.33a	198.00b	215.67b
	Sick Fresh Mass (g)				
Weekly	36.67	39.33	25.67	42.67	37.67
Fortnightly	44.33	40.00	38.67	29.33	30.00
	Commercial Dry Mass (g)				
Weekly	27.23	18.42	22.15	24.80	27.63
Fortnightly	29.04	25.84	23.60	20.47	23.29
	Number of Commercial Leaves				
Weekly	112.67b	97.67b	102.00b	111.33	139.00a
Fortnightly	129.67a	112.33a	118.33a	98.67	100.33b
	Number of Sick Leaves				
Weekly	30.00	26.00	22.00	38.67	33.00
Fortnightly	33.67	28.33	30.00	21.67	27.67
	Yield (bunch/m^2)				
Weekly	3.12	2.89	3.03	2.99	3.15
Fortnightly	3.16	2.99	3.10	3.01	3.09

Media followed by distinct letters in the long column between application range

for MFT and MFC are due to the weekly applications throughout the analyses. This is because the number of sprayings in these four weeks was higher than in the fortnightly applications and in a smaller time period, providing better protection against infection by Colletotrichum and making available the nutrients present in the components of the mixture. These results corroborate those found by Mazaro et al. (2013) when they evaluated the production and quality of strawberry under different concentrations of Bordeaux mixture, with the weekly applications showing more effectiveness at the concentration of 1.6%, very close to the 2% concentration used in the present study. Furthermore, the authors reported a reduction in the severity of Mycosphaerella leaf spot in the strawberry cultivar Camarosa, which explains that a reduction in the severity of anthracnose leads to an increase in chive production as it reduces the number of dead leaves.

With regard to the number of commercial leaves, the fortnightly application of Bordeaux mixture resulted in higher yield at the concentrations of 0.5% and 1.0%, whereas the weekly application was significantly more productive when dosed at 2.0% (**Figure 3**).

The higher efficiency of the Bordeaux mixture on the number of leaves can be explained by the availability of nutrients such as copper (Cu). This micronutrient is required in small quantities by plants and acts in the transport of electrons. Foliar fertilization using the

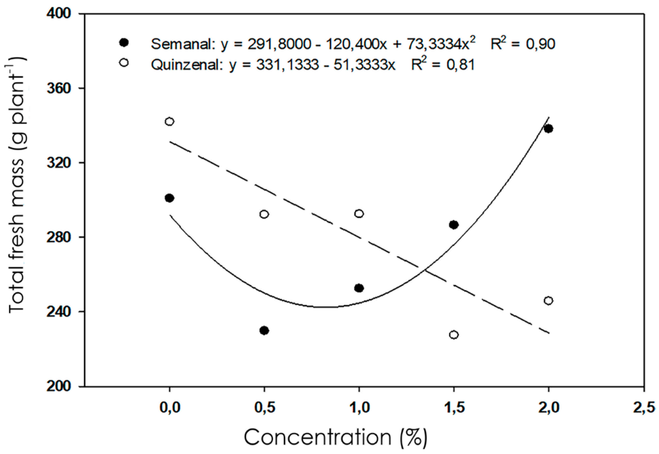

Figure 1 – Regression analysis for total fresh mass (MFT) of *A. fistulosum* under different concentrations of Bordeaux mixture (4th evaluation).

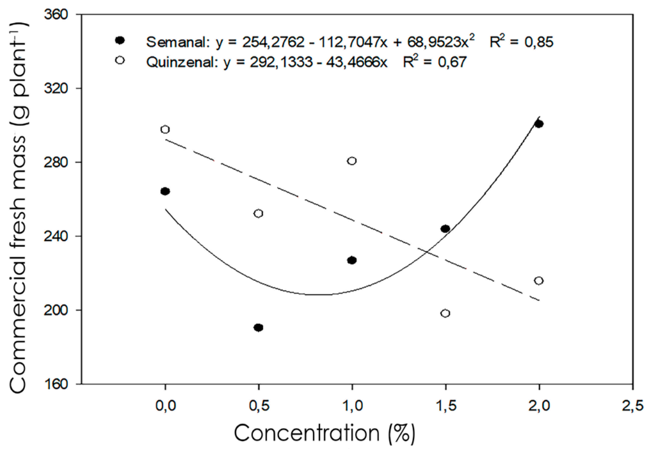

Figure 2 – Regression analysis for the Commercial Fresh Mass (MFC) of *A. fistulosum* under different concentrations of Bordeaux mixture (4th evaluation).

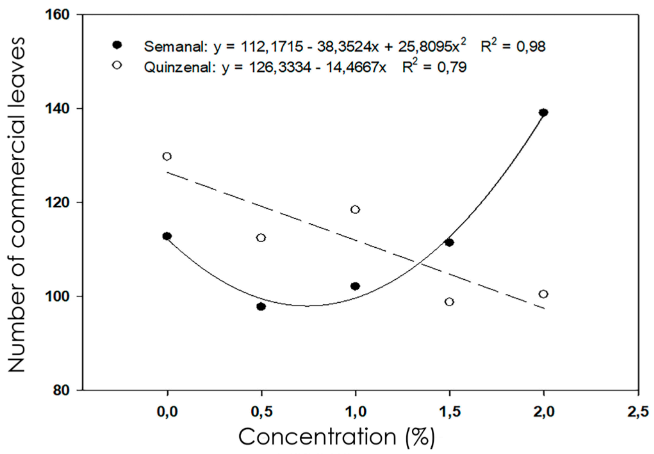

Figure 3 – Regression analysis for the number of commercial leaves (NFC) of *A. fistulosum* under different concentrations of Bordeaux mixture (4th evaluation).

Bordeaux mixture provides this micronutrient and prevents losses compared to fertilization via soil, which implies losses by leaching, for example (Vargas et al., 2019). Therefore, plants absorb Cu at an adequate content for their needs, resulting in better agronomic performance. Vargas et al. (2019) observed that the Bordeaux mixture can be recommended for lettuce cultivation, resulting in production gains.

There was no significant difference in the yield of *A. fistulosum* subjected to different doses of Bordeaux mixture for different periods (weekly and fortnightly applications). The low efficiency of the Bordeaux mixture could be related to the toxicity of its constituents, as is the case of copper sulfate at high concentrations. These results could also be related to the inadequate pH conditions that can interfere with the efficacy of this organic input, with a neutral pH being desirable to prevent sunburns (Silva et al., 2017).

However, significant statistical differences were obtained in the 4th week of evaluation with regard to the application times (weekly or fortnightly), which varied depending on the concentration of Bordeaux mixture applied. The positive results obtained with the weekly or fortnightly application of the mixture are mostly associated with the positive influence it has on plant metabolism, favoring their nutrition using the nutrients contained in the mixture's formulation and stimulating proteosynthesis, thus making plants more resistant (Sanchéz et al., 2002).

Future perspectives include the proposition of new studies that analyze the association of Bordeaux mixture with other organic fertilization sources to increase the yield of *A. fistulosum*, considering that studies have already concluded that the associated application of different sources of organic fertilization provides more satisfactory responses due to the greater availability of nutrients to plants, consequently resulting in higher yields.

Conclusions

The application of different concentrations of Bordeaux mixture does not interfere with the yield and anthracnose control in *Allium fistulosum*.

The application periods of Bordeaux mixture did not affect anthracnose control in chives.

The interaction observed in the 4th application with weekly sprayings of Bordeaux mixture at 2.0% was not effective in increasing the yield and/or controlling anthracnose.

The preventive application of Bordeaux mixture revealed not to be necessary for the cultivation of *A. fistulosum*.

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