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ALLELOPATHIC EFFECT OF COVER CROP EXTRACTS ON GERMINATION AND INITIAL GROWTH OF WEEDS

EFEITO ALELOPÁTICO DE EXTRATOS DE PLANTAS DE COBERTURA SOBRE A GERMINAÇÃO E CRESCIMENTO INICIAL DE PLANTAS DANINHAS

EFECTO ALELOPÁTICO DE EXTRACTOS DE PLANTAS DE COBERTURA SOBRE LA GERMINACIÓN Y EL CRECIMIENTO INICIAL DE PLANTAS INVASORAS

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ABSTRACT

The intensive use of herbicides has contributed to the selection of resistant weed populations, highlighting the need for alternative weed management strategies. In this context, allelopathy from cover crops may represent a complementary tool for weed suppression. This study aimed to evaluate the allelopathic potential of aqueous extracts from the shoot biomass of brachiaria (*Brachiaria ruziziensis*), sunn hemp (*Crotalaria ochroleuca*), and pearl millet (*Pennisetum glaucum*) on the germination and early development of Italian ryegrass (*Lolium multiflorum*), wild radish (*Raphanus sativus* L.), and beggarticks (*Bidens pilosa*). The experiment was conducted in a completely randomized design, using aqueous extracts at 10% (w/v). Germination percentage and speed, shoot and root length, and fresh and dry biomass accumulation were evaluated. Brachiaria and sunn hemp extracts significantly reduced all evaluated variables for the three weed species. Pearl millet extract showed a less pronounced allelopathic effect, with no significant interference on germination and dry biomass accumulation of wild radish. These results indicate that brachiaria and sunn hemp exhibit high allelopathic potential and may be used as complementary tools for sustainable weed management.

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Keywords Allelopathy. Resistance. *Bidens pilosa*. *Brachiaria ruziziensis*. *Crotalaria ochroleuca*.

RESUMO

O uso intensivo de herbicidas tem contribuído para a seleção de populações de plantas daninhas resistentes, evidenciando a necessidade de estratégias alternativas de manejo. Nesse contexto, a alelopatia de plantas de cobertura pode representar uma ferramenta complementar para a supressão de plantas daninhas. Este estudo teve como objetivo avaliar o potencial alelopático de extratos aquosos da biomassa da parte aérea de braquiária (*Brachiaria ruziziensis*), crotalária (*Crotalaria ochroleuca*) e milheto (*Pennisetum glaucum*) sobre a germinação e o desenvolvimento inicial de azevém (*Lolium multiflorum*), nabo (*Raphanus sativus* L.) e picão-preto (*Bidens pilosa*). O experimento foi conduzido em delineamento inteiramente casualizado, utilizando extratos aquosos a 10% (m/v). Foram avaliados a porcentagem e a velocidade de germinação, o comprimento da parte aérea e da raiz, e o acúmulo de biomassa fresca e seca. Os extratos de braquiária e crotalária reduziram significativamente todas as variáveis avaliadas para as três espécies de plantas daninhas. O extrato de milheto apresentou efeito alelopático menos pronunciado, sem interferência significativa na germinação e no acúmulo de biomassa seca do nabo. Esses resultados indicam que a braquiária e a crotalária apresentam alto potencial alelopático e podem ser utilizadas como ferramentas complementares no manejo sustentável de plantas daninhas.

Palavras-chave: Alelopatia. Resistencia. *Bidens pilosa*. *Brachiaria ruziziensis*. *Crotalaria ochroleuca*.

RESUMEN

El uso intensivo de herbicidas ha contribuido a la selección de poblaciones de malezas resistentes, evidenciando la necesidad de estrategias alternativas de manejo. En este contexto, la alelopatía de plantas de cobertura puede representar una herramienta complementaria para la supresión de malezas. Este estudio tuvo como objetivo evaluar el potencial alelopático de extractos acuosos de la biomasa de la parte aérea de braquiaria (*Brachiaria ruziziensis*), crotalaria (*Crotalaria ochroleuca*) y mijo perla (*Pennisetum glaucum*) sobre la germinación y el desarrollo inicial de raigrás (*Lolium multiflorum*), nabo (R*aphanus sativus L.*) y amor seco (Bidens pilosa). El experimento se realizó bajo un diseño completamente al azar, utilizando extractos acuosos al 10% (m/v). Se evaluaron el porcentaje y la velocidad de germinación, la longitud de la parte aérea y de la raíz, y la acumulación de biomasa fresca y seca. Los extractos de braquiaria y crotalaria redujeron significativamente todas las variables evaluadas para las tres especies de malezas. El extracto de mijo perla presentó un efecto alelopático menos pronunciado, sin interferencia significativa en la germinación ni en la acumulación de biomasa seca del nabo. Estos resultados indican que la braquiaria y la crotalaria presentan un alto potencial alelopático y pueden ser utilizadas como herramientas complementarias en el manejo sostenible de malezas.

Palabras clave: Alelopatía. Resistencia. *Bidens pilosa. Brachiaria ruziziensis. Crotalaria ochroleuca*.

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1 INTRODUCTION

Annual crops play a central role in Brazilian agricultural systems, favored by edaphoclimatic conditions that allow the continuous expansion of cultivated areas. However, weed interference represents one of the main limiting factors for crop productivity due to competition for water, light, nutrients, and space, in addition to significantly increasing production costs associated with weed control.

Weed management in Brazilian agriculture is largely dependent on chemical control, which has led to escalating use of herbicides and contributed to resistant weed populations, posing economic, agronomic, and environmental challenges (Procópio et al. 2024). Moreover, the intensification of herbicide use is associated with environmental and human health risks, and Brazil is among the world's largest consumers of these products (Cassal et al. 2014).

Given this scenario, alternative and complementary strategies to chemical control have been widely discussed, particularly the use of cover crops in integrated weed management. Among the mechanisms associated with these species, allelopathy has received increasing attention, as certain plants are capable of releasing chemical compounds that interfere with the germination and early development of other species present in the same environment (Rice. 1984).

Allelopathy involves the release of primary and secondary metabolites that may act directly or indirectly on essential physiological processes, such as germination and early seedling growth. Studies have demonstrated that residues or aqueous extracts from cover crops can exert suppressive effects on other plant species, reducing seed germination and early seedling development. Fracasso et al. (2018) reported that residues of winter crops, such as wheat, ryegrass, and oats, significantly affected the germination and initial growth of corn and soybean under controlled conditions, indicating the potential of cover crops to interfere with plant establishment and reduce dependence on synthetic herbicides.

In this context, cover crops such as brachiaria (Brachiaria ruziziensis), crotalaria (Crotalaria ochroleuca), and millet (Pennisetum glaucum) present allelopathic potential that is still poorly explored against important agricultural weed species, such as ryegrass (Lolium multiflorum), forage radish (Raphanus sativus L.), and beggarticks (Bidens pilosa).

Thus, the objective of this study was to evaluate the allelopathic potential of aqueous extracts from the shoot biomass of cover crops (brachiaria, crotalaria, and millet) on the germination and early development of ryegrass, forage radish, and beggarticks.

2 MATERIALS AND METHODS

The experiment was conducted at the Federal University of Technology – Paraná (UTFPR), Dois Vizinhos campus, Brazil. The cover crops used were brachiaria (*Brachiaria ruziziensis*), crotalaria (*Crotalaria ochroleuca*), and millet (*Pennisetum glaucum*). The species were broadcast-sown in 1.5 × 1.5 m plots and allowed to grow for 60 days, corresponding to the period commonly observed in agricultural areas during the off-season.

After this period, the plants were cut close to the soil surface, and only the shoot biomass was used. The plant material was dried in a forced-air oven at approximately 31 °C for four days and subsequently ground in a knife mill until a fine powder was obtained for the preparation of aqueous extracts.

The weed species evaluated were ryegrass (*Lolium multiflorum*), forage radish (*Raphanus sativus* L.), and beggarticks (*Bidens pilosa*). Seeds were obtained from the cold storage chamber of the UTFPR seed laboratory, Dois Vizinhos campus.

For the preparation of aqueous extracts, 100 g of dried and ground material from each cover crop were mixed with 1,000 mL of distilled water, establishing a 10% (w/v) proportion. The suspensions were kept at rest for 24 hours at room temperature and subsequently filtered using filter paper, yielding the liquid extracts used in the treatments. The pH of the extracts was measured at the beginning of the experiment to verify possible interference with the results.

The experiment was arranged in a completely randomized design, in a factorial scheme consisting of four treatments (control, brachiaria extract, crotalaria extract, and millet extract) and three weed species, with four replicates. The germination test was carried out in plastic germination boxes (gerbox), using four sheets of germination paper per experimental unit. The volume of extract applied to each gerbox was 8 mL, corresponding to 2.5 times the dry mass of the paper, following standard procedures for seed germination tests.

In each experimental unit, 36 seeds of each weed species were distributed separately. The boxes were placed in a germination chamber at 25 °C for seven days. Evaluations were performed daily, and seeds were considered germinated when radicle protrusion exceeded 2 mm.

Germination percentage (%G) and germination speed index (GSI) were evaluated. Germination percentage was calculated as the ratio between the number of germinated seeds and the total number of seeds sown, expressed as a percentage. The GSI was

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determined by summing the number of germinated seeds each day and dividing by the corresponding time elapsed.

At the end of the germination test, shoot length, root length, and fresh mass of the seedlings were measured. Subsequently, the material was dried in an oven at 100 °C for 24 hours to determine dry mass.

The data were subjected to analysis of variance (F test), and means were compared using Tukey's test at a 5% probability level. Statistical analyses were performed using SAS software (Analytics Software & Solutions).

3 RESULTS AND DISCUSSION

3.1 HYDROGEN POTENTIAL (pH)

The pH values of the cover crop extracts ranged from 6.0 to 7.0 (Table 1), falling within the neutral to slightly acidic range.

Table 1

pH values of the control and aqueous extracts of cover crop shoots

Treatments	pH
Control	7,0
Brachiaria Extract	7,0
Crotalaria Extract	6,5
Millet Extract	6,0

The observed pH variations do not represent physiological limitations to the germination process or the initial development of the evaluated cultivars. Literature regarding the isolated influence of pH in allelopathy bioassays is scarce; however, studies with *Isocoma drummondii* indicate that germination reductions occur only under extreme acidity levels (pH = 2.0), while solutions in the 3.0 to 11.0 range do not promote significant alterations (MAYEUX; SCIFRES, 1978).

3.2 SEED GERMINATION AND GERMINATION SPEED INDEX (GSI)

There was a significant effect of the aqueous extracts on both germination percentage (%G) and germination speed index (GSI) of the evaluated weeds (Tables 2 and 3). *Brachiaria* sp. and *Crotalaria* sp. extracts promoted the most pronounced reductions in both variables, surpassing the inhibition caused by the pearl millet (*Pennisetum glaucum*) extract.

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Table 2

Mean germination percentage (%G) and coefficient of variation (CV%) of weed seeds under different treatments

	Germination percentage (%)				
	Control	Brachiaria Extract	Crotalaria Extract	Millet Extract	CV
Ryegrass	95a	16,4c	22,1c	43,6b	20,9
Forage radish	59,3a	22,1b	23,5b	52,1a	14,4
Beggarticks	87,8a	5,0c	0,73c	39,3b	43,8

Means followed by the same letter in the row do not differ from each other according to Tukey's test ($p < 0.05$).

The allelopathic potential of *Brachiaria* was evidenced by a reduction exceeding 80% in ryegrass germination and 90% in beggarticks. Similar results were reported by Rotta and Coelho (2016), who observed inhibition of beggarticks germination using *B. ruziziensis* extracts. However, the allelopathic response is species-dependent; Fagioli et al. (2000) found no inhibitory effects of *B. brizantha* and *B. decumbens* extracts on pigeon pea seeds, suggesting selectivity of the involved allelochemicals. Regarding *Crotalaria*, %G inhibition approached 100% for beggarticks. Although Araújo et al. (2008) observed no allelopathic effect of *C. juncea* on this weed at low concentrations, Teixeira et al. (2003) confirmed the susceptibility of beggarticks to extracts of this legume, corroborating the present data.

Table 3

Mean germination speed index (GSI) of weed seeds under different treatments and coefficient of variation (CV%)

	Germination speed index				
	Control	Brachiaria Extract	Crotalaria Extract	Millet Extract	CV
Ryegrass	40,1a	0,97c	3,05c	11,5b	15,5
Forage radish	27,5a	6,5c	9,59c	18,9b	19,9
Beggarticks	39,3a	0,70c	0,075c	10,9b	31,4

Means followed by the same letter in the row do not differ from each other according to Tukey's test ($p < 0.05$).

The GSI showed a homologous behavior to germination, with severe reductions under the influence of Brachiaria and Crotalaria (Table 3). The reduction in germination speed is an indicator of physiological stress, resulting in seedlings that are less competitive for light and nutrient resources (SILVEIRA, 2010).

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3.3 SHOOT AND ROOT LENGTH

Initial seedling growth was severely compromised by exposure to the aqueous extracts (Tables 4 and 5). For all three weed species, a drastic reduction in shoot length (SL) and root length (RL) was observed, particularly for beggarticks and wild radish, which showed zero or near-zero growth under the influence of *Brachiaria* and *Crotalaria*

Table 4

Mean shoot length of germinated weed seeds under different treatments and coefficient of variation (CV%).

	Shoot length (cm)				
	Control	Brachiaria Extract	Crotalaria Extract	Millet Extract	CV
Ryegrass	6,24a	0,29b	0,31b	0,27b	14,4
Forage radish	3,6a	0,03c	0,00c	0,34b	45,6
Beggarticks	4,01a	0,00b	0,00b	0,00b	19,8

Means followed by the same letter in the row do not differ from each other according to Tukey's test ($p < 0.05$).

Table 5

Mean root length of germinated weed seeds under different treatments and coefficient of variation (CV%)

	Root length (cm)				
	Control	Brachiaria Extract	Crotalaria Extract	Millet Extract	CV
Ryegrass	5,0a	0,0b	0,0b	0,24b	13,2
Forage radish	3,05a	0,45b	0,46b	0,81b	47,4
Beggarticks	2,88a	0,13c	0,02c	0,79b	24

Means followed by the same letter in the row do not differ from each other according to Tukey's test ($p < 0.05$).

The root system was the most sensitive structure to the action of allelochemicals (Table 5). Direct contact of the roots with the aqueous solutions enhances the absorption of phytotoxins, resulting in root atrophy. This root suppression is ecologically relevant, as it limits soil exploration and nutrient uptake, increasing weed vulnerability to water stress and competition with the main crop.

3.4 FRESH AND DRY SEEDLING MASS

The reductions in fresh mass (FM) and dry mass (DM) reflected the inhibitory effect observed in initial growth (Tables 6 and 7).

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Table 6

Mean fresh mass of germinated weed seedlings under different treatments and coefficient of variation (CV%)

Fresh matter					
	Control	Brachiaria Extract	Crotalaria Extract	Millet Extract	CV
Ryegrass	0,27a	0,01c	0,02bc	0,04b	13
Forage radish	1,02a	0,16c	0,18c	0,50b	22,4
Beggarticks	0,375a	0,008b	0,001b	0,060b	25,4

Means followed by the same letter in the row do not differ from each other according to Tukey's test ($p < 0.05$).

Table 7

Mean dry mass of germinated weed seedlings under different treatments and coefficient of variation (CV%)

Dry matter					
	Control	Brachiaria Extract	Crotalaria Extract	Millet Extract	CV
Ryegrass	0,052a	0,007c	0,015c	0,027b	20,3
Forage radish	0,21a	0,08b	0,08b	0,19a	15,9
Beggarticks	0,0527a	0,0042c	0,005c	0,00b	49,5

Means followed by the same letter in the row do not differ from each other according to Tukey's test ($p < 0.05$).

DM reduction was most pronounced in beggarticks, reaching total suppression under pearl millet and Crotalaria extracts. The discrepancy between the observed effects highlights the selectivity of secondary metabolites, reinforcing the use of cover crops as a strategic tool in integrated weed management.

5 CONCLUSION

The aqueous extracts of the evaluated cover crops exhibited significant allelopathic potential on the germination and early development of the studied weed species. Extracts from brachiaria (*Brachiaria ruziziensis*) and crotalaria (*Crotalaria ochroleuca*) were the most effective, consistently suppressing germination, vigor, and initial growth of ryegrass (*Lolium multiflorum*), wild radish (*Raphanus raphanistrum*), and beggarticks (*Bidens pilosa*).

Conversely, pearl millet (*Pennisetum glaucum*) extract showed a selective allelopathic effect, with limited interference on the germination and biomass accumulation of wild radish. Overall, these results indicate that incorporating cover crops with high allelopathic potential—particularly brachiaria and crotalaria—serves as a viable complementary strategy for sustainable weed management, potentially reducing the reliance on chemical control.

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