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Article

Analysis of Genotypic Variability in *Avena* spp. Regarding Allelopathic Potentiality

Análise da Variabilidade Genotípica em ***Avena*** *spp. Quanto à Potencialidade Alelopática*

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ABSTRACT - The recognized allelopathic activity of oats as a soil-cover plant induces the study of the potential of their germplasm. The objective of this study is to verify if there is genotype variability in the *Avena* spp. with regard to allelopathic activity. Extracts of *A. strigosa* 'Agro Quaraí', 'Agro Esteio', 'Embrapa139', 'AF 12104', 'AF 12109', 'AF 12202', 'AF 12209', *A. sativa* 'UPFPS Farroupilha' and 'AF 1345 Ucraniana,' were prepared in three concentrations w/v (5 g, 10 g, and 20 g of dry mass 100 mL^{-1}). The experiment was conducted in a germination chamber for 15 days, with lettuce (*Lactuca sativa* L.) as the recipient plant. There was complete inhibition of germination under 20% w/v extracts and partial inhibition at 10% w/v. Only 5% w/v observed a difference between the genotypes, in which the highest efficiency was obtained from the extracts of white oats and black oats 'AF 12104' and 'Agro Quaraí', which reduced germination between 92% and 97%. When the concentration increased above 5% w/v the harmful effect on germination was significantly greater. Only in extracts at 5% w/v there was a higher genotypic effect on germination, with variation in the germination rate index, root, and hypocotyl stretching. The genotype that had the least allelopathic effect was AF 12202, with an inhibitory mean in the evaluated attributes of 35%. The other genotypes inhibited the attributes of germination and seedling growth between 66% and 86%. With regard to the variability in the *Avena* spp., the allelopathic activity could be applied to obtain cultivars with greater weed suppressive power.

Keywords: *Avena sativa* L., *Avena strigosa* Schreb, weed, germination, inhibition.

RESUMO - A reconhecida atividade alelopática de aveias como plantas de cobertura do solo leva ao estudo do potencial de seus germoplasmas. O objetivo deste trabalho foi verificar se há variabilidade genotípica em ***Avena*** *spp. quanto à atividade alelopática. Os extratos de* ***A. strigosa*** *Agro Quaraí, Agro Esteio, Embrapa 139, AF 12104, AF 12109, AF 12202, AF 12209 e de* ***A. sativa*** *UPFPS Farroupilha e AF 1345 Ucraniana foram preparados em três concentrações p/v (5, 10 e 20 g de massa seca 100 mL*$^{-1}$*). O ensaio foi conduzido em câmara de germinação durante 15 dias, tendo alface (****Lactuca sativa*** *L.) como planta receptora. Houve total inibição da germinação sob extratos a 20% p/v einibição parcial a 10% p/v. Somente a 5% p/v observou-se diferença entre os genótipos, em que a maior eficiência foi dos extratos das aveias-brancas e das aveias-pretas AF 12104 e Agro Quaraí, que reduziram a germinação entre 92% e 97%. O efeito deletério sobre a germinação foi significativamente maior à medida que a concentração aumentou acima de 5% p/v, com variação sobre o índice de velocidade de germinação, alongamento radicial e de hipocótilo. O genótipo com menor efeito alelopático foi AF 12202, com inibição média de 35% nos atributos avaliados. Os demais*

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*genótipos inibiram a germinação e o crescimento de plântula entre 66% e 86%. A variabilidade em **Avena** spp. quanto à atividade alelopática pode ser aplicada para obtenção de cultivares com maior poder supressivo das plantas daninhas.*

Palavras-chave: *Avena sativa*, *Avena strigosa*, planta daninha, germinação, inibição.

INTRODUCTION

White oats (*Avena sativa* L.) and black oats (*A. strigosa* Schreb.) are cultivated in temperate and subtropical regions under a crop rotation system. They are recognized by their rapid growth and high capacity to suppress weeds, due to their allelopathic potential (Price et al., 2006; Ahmad et al., 2014).

In the genetic improvement of oats (*Avena* spp.), evaluation of the allelopathic potential of the germplasm is not contemplated, as it restricts understanding of the influence of the oat cultivars on weeds. In another perspective, Bertholdsson (2007), points out that most of the characters used in breeding programs invariably obtain cereal cultivars for conventional and organic systems, although a characteristic of organic agriculture is the competitive ability of weeds.

Accessing and understanding the inter- and intra-specific variability in plants used for soil cover or crop rotation, in relation to allelopathic weed suppressor potential, can prove to be strategic functional descriptors of value aggregation to cultivars and offer criteria for the acquisition of seeds by the producer. Allelopathy is defined as any direct or indirect, beneficial or harmful effect of a plant or microorganism, by producing chemical compounds involving secondary metabolism, which are released into the environment (Silva et al., 2011).

The use of plants with allelopathic potential in agriculture, especially in systems that alternate between annual winter and summer crops, is a means of reducing weed infestation. However, this control comes from other attributes, besides the release of allelopathic compounds, such as, the physical effect of the straw, the inactivation of the dormant mechanisms, or the formation of a physical barrier that prevent the germination and survival of the germinated seeds on the surface of the soil (Gomes Jr and Christoffoleti, 2008).

The allelopathic action of oats is due to the exudation of substances such as scopoletin and ferulic, p-coumaric, siringeic, vanillic, and p-hydroxybenzoic acids whose concentrations depend on the genotype and environmental conditions of plant cultivation (Jacobi and Fleck, 2000; Esposito et al., 2008; Lupini et al., 2014; Chini, 2017). It is known that the allelopathic potential of white oats on ryegrass (*Lolium multiflorum* Lam.) and wheat depends of the exuded amount of scopoletin from the roots (Jacobi and Fleck, 2000). Thus, the cultivation of oats, whaich has a greater allelopathic activity may be a good strategy in weed control, together with herbicide use (Santi et al., 2003; Hagemann et al., 2010).

The effects caused by allelopathic compounds may vary in intensity and concentration, depending on the species under study, on the target organism, soil characteristics, temperature, and water conditions. Phytochemicals with allelopathic activity are isolated and identified from studies with different plant species, to be used in agriculture as alternatives in the fight against vectors and pests, by interrupting their development cycle (Duke et al., 2002).

The first step in the studies with allelochemicals is conducted by means of laboratory bioassays with the use of crude plant extracts, in order to look for allelopathic activity of the genotypes. The allelopathy of the chemical compounds is reflected in the recipient species, with stimulation or inhibition of germination and seedling growth (Souza Filho et al., 2010). Thus, the main focus of the allelopathic studies is the control of weeds through the use of plants that have heterotoxic action on seeds and invasive seedlings.

In this study we test the hypothesis that the allelopathic activity of white oats and black oats is genotype-dependent. It is dependent on the concentration of the extract. This study aims to verify that there is variability among oat genotypes with regard to the allelopathic activity of extracts involved with the aerial part of the plants, in three concentrations.

MATERIAL AND METHODS

Relationship of treatments

The plant material used in the elaboration of the extracts came from the aerial part of nine oat genotypes harvested during the full flowering stage. The black oat genotypes were: Three cultivars (Agro Quaraí, Agro Esteio, and Embrapa 139) and four lines (AF 12104, AF 12109, AF 12202, and AF 12209) and the white oat genotypes were: One cultivar (UPFPS Farroupilha) and one line (AF 1345 Ucraniana). The plants were cultivated simultaneously in the 2016 crop, in a Red Latosol Distrophic, in Passo Fundo, at 28°13'45,12" S and 52°19'43,80" W, at an altitude of 692 m. The biomass of the aerial parts was harvested manually, when the plants reached the full flowering stage, and constituted, on an average, 19% of panicles, 56% of stems and 25% of leaf blades. To test the allelopathic activity of the extracts, lettuce was used as a recipient species. Lettuce was considered to be one of the species indicative of allelopathic activity, because it presented fast and uniform germination and a degree of sensitivity that allowed to express the results under low concentrations of allelopathic substances (Ferreira and Áquila, 2000; Wandscheer and Pastorini, 2008; Wandscheer et al., 2011).

Experimental design

The research was experimental and explanatory of the type of association with interference. The bioassay was explained from a differentiated factorial (9 x 3) + 1 (control), the determining factors of which were, genotype and extract concentration, respectively, with inclusion of distilled water as control treatment to test the allelopathic effect. In this manner, 27 genotype-concentrated plant extracts were tested, which resulted from the combination of nine oat genotypes and three concentrations (5%, 10% and 20% w/v). The experimental design was completely randomized with four replicates. The experimental units consisted of gearboxes with two sheets of germitest filter paper.

Preparation and conduction of the experiment

The plant material used in the elaboration of the extracts came from the aerial part of the plants of the oat genotypes, harvested in the full flowering stage. After harvesting, the material was chopped, when still green, into pieces of approximately 1 cm. They were then dried in a forced air heater oven at 45 °C until constant weight was obtained, followed by milling in Wiley type mill (0.5 mm) until a homogeneous powder was obtained, to be used in the preparation of extracts (Chini, 2017). The material was stored in a refrigerator at 4 °C till future use.

In the elaboration of extracts, the static maceration method was chosen, by immersion of the vegetal material in distilled water, followed by rest for 24 hours at room temperature, and under light (Soares and Vieira, 2000). The concentrations of 5%, 10% and 20% w/v resulted from the immersion of 5 g, 10 g, and 20 g of dry material in 100 mL^{-1} of distilled water, respectively. Following this, filtration was done in order to obtain a pure liquid. The extracts presented a pH, in the universal indicator paper, with values between 6 and 7.5, considered not limiting for the germination of seeds (Laynez-Garsaball and Mendez-Natera, 2006). The extracts were made with distilled water, which presented low concentrations of sodium and chloride ions, preventing salinity from interfering with seed germination (Masondo et al., 2018).

The bioassay was conducted in a BOD-type germination chamber, with a constant temperature (25 °C) and 12 hour photoperiod (Brasil, 2009; Wandscheer et al., 2011). Germitest paper sheets and 10 mL extracts or distilled water were added to the gearboxes, previously disinfected with 70% alcohol. The lettuce diaspores (achenes) were previously disinfected by immersion in 1% sodium hypochlorite solution for three minutes, followed by washing in distilled water. Subsequently, fifty diaspores were arranged on the germitest filter paper in each gearbox. The diaspores and later the seedlings were kept in the germination chamber for 15 days, wherein, germination evaluations were carried out daily, for ten days, until the initial growth of the seedlings on the fifteenth day.

Evaluations

The evaluation of the allelopathic activity on the germination of the seeds was done by counting of the germinated seeds daily, during ten days. The seeds were considered germinated when they presented a 2 mm radicular protrusion (Ferreira and Áquila, 2000). At the end of this time the percentage of germination and the germination velocity index (GVI) were calculated according to the study of Ranal and Santana (2006). The action of the extracts on the seedlings was examined on the fifteenth day of the experiment, by measuring the length from the primary root to the hypocotyl, with a digital caliper. After analysis of variance, according to the Dunnett's test, the percentage of inhibition (Inhibition %) (Abbott, 1925) was calculated for the extracts that showed an allelopathic activity on germination, GVI, root and hypocotyl elongation:

$$Inhibition(\%) = \left(\frac{xc - xt}{xc}\right) x100$$

where, *xc* was the mean obtained from the control treatment and *xt* was the mean obtained from the treatment.

Next, the extracts were classified as effective (≥ 50% inhibition) or potentially (≥ 35% inhibition) allelopathic (Souza Filho and Mourão Jr., 2010). In this manner, the ones with inhibition in the range of 35% to 49% were considered potentially inhibitory extracts.

In this study, we specifically evaluated, (1) whether the genotype from which the extract material was obtained had an inhibitory effect on the attributes of germinability of lettuce seedlings (*Lactuca sativa*), regardless of the amount extracted, (2) whether the increase in the concentration of the extracts increased the inhibitory power of the extracts, independently of the genotype, and (3) whether the factors were interactive and jointly determined the activity of the extracts on the germination and growth of seedlings of the recipient plant.

Statistical Analysis

The germination data were submitted to analysis of variance (ANOVA) in a differential factorial arrangement (9 x 3) +1 (control), to compare the effect of the plant extracts with the control treatment (distilled water), using the Dunnett test, at 5% probability of error, followed by a comparison between the extracts, using the Scott-Knott test at 5% probability of error. Following the verification that 14 extracts totally inhibited the germination, which resulted in the absence of numerical data related to GVI and seedling elongation, the ANOVA was done in a unifatorial model. Thus, the remaining 13 genotype-concentrate extracts were compared with the control treatment by the Dunnett's test at 5% probability, and the comparisons were made between the extracts by the Scott-Knott's test at 5% probability. The analyses were performed with the statistical program Assistat (Silva and Azevedo, 2002).

RESULTS AND DISCUSSION

Effect of extracts on seed germination

The extracts compared to the control treatment were effectively allelopathic (inhibition ≥ 50%) in the germination of lettuce seeds, according to the study of Souza Filho and Mourão Jr. (2010), with a significant effect of genotype x concentration on this attribute (Table 1). At 10% w/v the extracts did not show

Table 1 - Genotype effect of oat (*Avena* spp.) and extract concentration on the lettuce seeds germination percentage. Passo Fundo, 2017

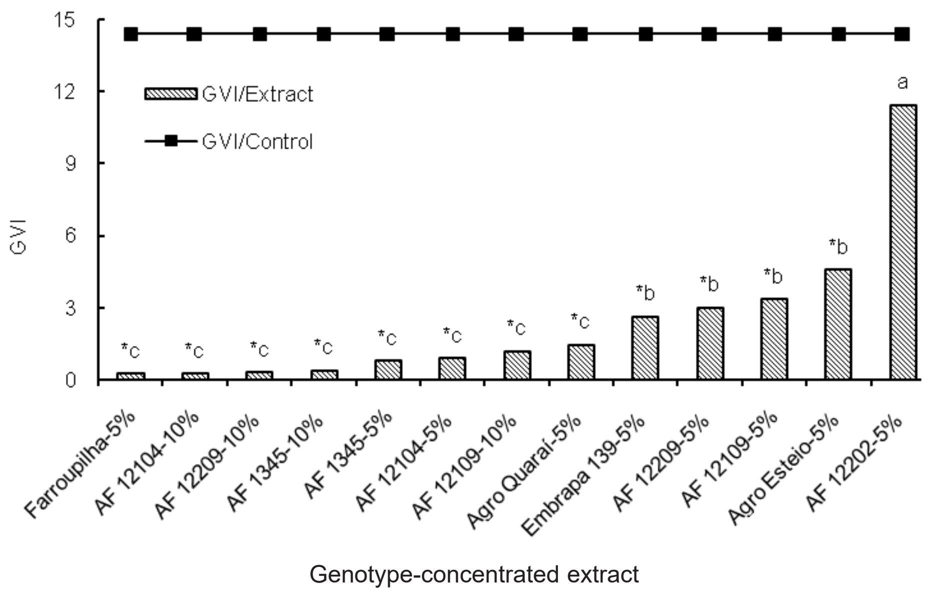
Genotype	Concentration[1]		
	5% w/v	10% w/v	20% w/v
UPFPS Farroupilha[2]	*3 dA	*0 ns A	*0 ns A
AF 12104[3]	*5 dA	*1 ns A	*0 ns A
AF 1345 Ucraniana[2]	*8 dA	*4 ns A	*0 ns A
Agro Quaraí[3]	*8 dA	*0 ns B	*0 ns B
Embrapa 139[3]	*15 cA	*0 ns B	*0 ns B
AF 12109[3]	*16 cA	*5 ns B	*0 ns B
AF 12209[3]	*18 cA	*2 ns B	*0 ns B
Agro Esteio[3]	*28 bA	*0 ns B	*0 ns B
AF 12202[3]	*49 aA	*0 ns B	*0 ns B
Control (distilled water) = 100%			

* It Indicates significant difference related to the control treatment by the Dunnett ($p < 0.05$) test. Averages followed by the same letter in lower case, in column, upper case, in line, don't statistically differ among them by the Scott-Knott ($p > 0.05$) test; ns = not significant ($p > 0.05$). [1] g of dry plant material/100 mL^{-1} of distilled water. [2] White oats. [3] Black oats.

any difference ($p > 0.05$), hence, the genotypic effect ($p < 0.05$) on the allelopathic action on germination was evidenced only at the lowest concentration (5% w/v). In this concentration, the genotypes UPFPS Farroupilha, AF12104, AF1345 Ucraniana, and Agro Quaraí had the most heterotoxic effect on germination, with a mean inhibition of 94%. The extract with a lower allelopathic effect was elaborated with the black oat line AF 12202-5%, which reduced the germination by 51%. Finally, with the other extracts at 5% w/v, all elaborated with the black oat line, there was inhibition of 72% to 84% in the germination of seeds of the indicator plant.

As for the extracts elaborated with the biomass of white oats, the allelopathies of UPFPS Farroupilha and UPFPS 1345 Ucraniana and black oat biomass AF 12104 were also shown to be inhibitory to seed germination, in the three concentrations tested. For the other genotypes, the deleterious effect on germination was significantly higher as the concentration increased from 5% w/v to 10% w/v or 20% w/v.

Of the 27 extracts tested, only 13 did not completely inhibit seed germination, which is why it was possible to evaluate the other attributes, such as GVI, root length, and hypocotyl. Among these three attributes, most of the allelopathic extracts were generally made at 10% w/v (Figures 1 and 2). Regarding GVI, all extracts, except AF 12202-5%, delayed germination. In this respect, the best allelopathic extracts were UPFPS Farroupilha-5%, AF 12104-10%, AF 12209-10%, AF 1345 Ucraniana (5% and 10%), AF 12104-5%, AF 12109-10%, and Agro Quai-5% (Figure 1).



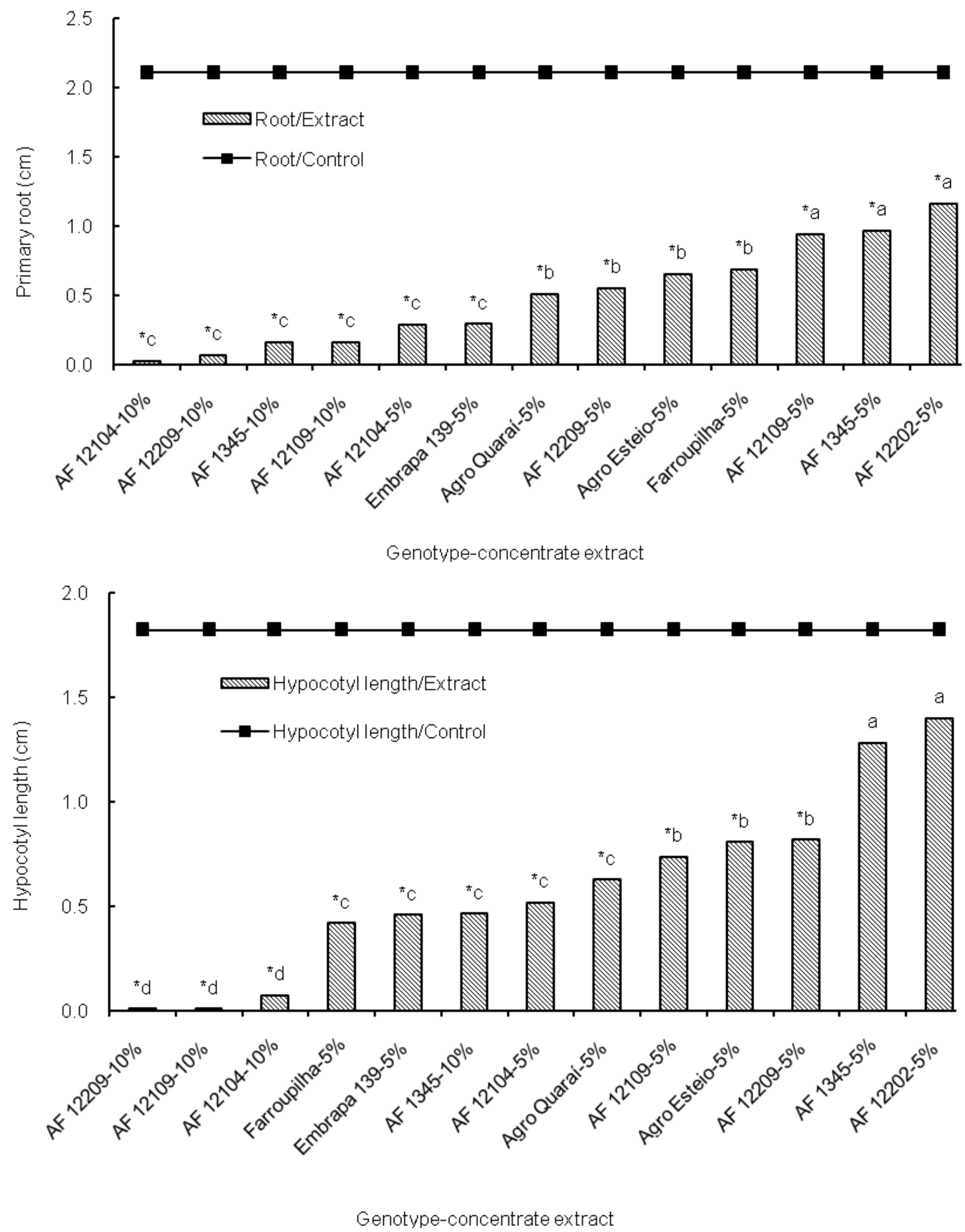
* It Indicates difference related to the control treatment (distilled water) by the Dunnett ($p < 0.05$) test. Different letters on the columns indicate significant difference among the extracts by the Scott-Knott ($p > 0.05$) test.

Figure 1 - Effect of aqueous extracts elaborated with biomass of oat genotypes (*Avena* spp.) in concentrations of 5% and 10% w/v, on the germination velocity index (GVI) of lettuce (*Latuca sativa*). Passo Fundo, 2017.

Effect of extracts on seedling growth

In root elongation, all extracts were allelopathic, as they differed from the control treatment ($p < 0.05$) (Figure 2). The extracts AF 12104 (5% and 10%), AF 12209-10%, AF 1345 Ucraniana-10%, AF 12109-10%, and Embrapa 139-5% were the ones that inhibited the growth of the primary root, in contrast to the extracts AF 12109-5%, AF 1345 Ucraniana-5%, and AF 12202-5%, which showed a lower allelopathic effect.

For the most innocuous extracts, similarity in the length of the hypocotyl was verified in relation to the effect on the root. The extracts AF 1345-5% and AF 12202-5% were not allelopathic for elongation of the aerial part of the seedlings, as they did not differ from the control treatment (Figure 2).



* It indicates difference in control treatment (distilled water) by the Dunett test ($p < 0.05$). Different letters on the columns indicate a significant difference by the Scott-Knott test ($p < 0.05$).

Figure 2 - Effect of aqueous extracts elaborated with biomass of oat genotypes (*Avena* spp.), in concentrations of 5 and 10% w/v, on the primary root and hypocotyl length of lettuce seedlings (*Lactuca sativa*). Passo Fundo, 2017.

The effect of genotype-concentrated extracts that showed allelopathic action on germination and elongation of lettuce seedlings ranged from potentially allelopathic (35% to 49% inhibition) to effectively allelopathic (≥ 50% inhibition), according to the criterion of Souza Filho and Mourão Jr. (2010) (Table 2). All extracts were effectively inhibitory to seed germination, inhibiting 51% to 100% extrusion of the primary roots and hypocotyl (Table 1).

Of the 13 extracts that partially acted on germination, allowing the elongation of seedlings, only AF 12202-5% was not potentially or effectively inhibitory for GVI and hypocotyl elongation, as it was not allelopathic for these attributes (Figures 1 and 2). This extract was the one with the

Table 2 - Synopsis of the type of allelopathic effect of aqueous extracts elaborated with biomass of oat genotypes (*Avena* spp.) in concentrations of 5%, 10%, and 20% w/v on attributes of germinability and stretching of lettuce seedlings (*Lactuca sativa*). Passo Fundo, 2017

Extract	Inhibitoryeffect			
	Germination	GVI[1]	Root	Hipocotyl
UPFPS Farroupilha-5%	(++)	(++)	(++)	(++)
UPFPS Farroupilha-10%	(++)	-	-	-
UPFPS Farroupilha-20%	(++)	-	-	-
AF 1345 Ucraniana-5%	(++)	(++)	(++)	(NA)
AF 1345 Ucraniana-10%	(++)	(++)	(++)	(++)
AF 1345 Ucraniana-20%	(++)	-	-	-
AF 12104-5%	(++)	(++)	(++)	(++)
AF 12104-10%	(++)	(++)	(++)	(++)
AF 12104-20%	(++)	-	-	-
AF 12109-5%	(++)	(++)	(++)	(++)
AF 12109-10%	(++)	(++)	(++)	(++)
AF 12109-20%	(++)	-	-	-
AF 12209-5%	(++)	(++)	(++)	(++)
AF 12209-10%	(++)	(++)	(++)	(++)
AF 12209-20%	(++)	-	-	-
Agro Quaraí-5%	(++)	(++)	(++)	(++)
Agro Quaraí-10%	(++)	-	-	-
Agro Quaraí-20%	(++)	-	-	-
Agro Esteio-5%	(++)	(++)	(++)	(++)
Agro Esteio-10%	(++)	-	-	-
Agro Esteio-20%	(++)	-	-	-
Embrapa 139-5%	(++)	(++)	(++)	(++)
Embrapa 139-10%	(++)	-	-	-
Embrapa 139-20%	(++)	-	-	-
AF 12202-5%	(++)	(NA)	(+)	(NA)
AF 12202-10%	(++)	-	-	-
AF 12202-20%	(++)	-	-	-

(NA): not allelopathic; (+) potentially; (++) effective. Conventional used signal. - Numeric data not available (absence of germinated seeds). [1] Germination velocity index.

lowest allelopathic action for root growth, being classified as potentially inhibitory. Similar response was verified with the extract AF 1345 Ucraniana-5%, that was effectively inhibitory to germination, GVI and root lengthening, but did not affect hypocotyl elongation (Figures 1 and 2).

Based on the main hypothesis tested here, it was verified that the allelopathic activity of white oats and black oats in this trial was genotype-dependent, depending on the extract concentration. If the allelopathic effect was only due to the genotype, under any extract concentration it would change the germination and growth of the seedlings. In contrast, if the allelopathic effect was entirely due to the extract concentration, the oats would be equally allelopathic. These assumptions were partially examined, because only the germination test, which is one of the main indicators of allelopathy in bioassays, was able to detect the genotype-concentration interactive effect (Table 1). As the seedlings were not obtained in the nine extracts at 20% and in the five extracts at 10%, it was necessary to continue the statistical analysis with the exclusion of these 14 extracts, and the unifatorial design was assumed for the other biological attributes evaluated (Figures 1 and 2).

However, the genotypic effect can be verified only in the germination test, which is one of the most significant indicators of allelopathy in bioassays. The difference between genotypes has been verified at the lowest concentrations tested. Because the genotypes tested are from different breeders, assuming that the selection and/or crossing are distinct, the genotype variability with respect to the allelopathy here the attested stems from the difference in genetic material. The allelopathy of the oats results from the allelochemicals present in the plant, which presuppose the variability among the genotypes, for this attribute (Price et al., 2006; Hagemann et al., 2010; Ahmad et al., 2014).

The difference between the genotypes and the allelopathic activity on germination was observed only in the lower concentration of the extracts (5%), suggesting that in the higher concentrations the amount of allelochemicals was too high to suppress the genotypic differences. In bioassays with *Avena* spp. (Hagemann et al., 2010) and canola (*Brassica napus*) (Rizzardi et al., 2008), similar results were obtained. In these, apart from having concentrations above those tested here, they also showed that only under less concentrated extracts was there a genotypic effect of allelopathic activity on germination.

With the need to confirm the results obtained in the laboratory, in the field, a test with the use of crude extracts is one of the most-used procedures for the prospection of allelopathic activity in the plants, allowing the action of the allelochemicals to be reflected in the recipient species (Souza Filho et al., 2010). Moreover, the use of lettuce has been aligned with what is usual in studies of this nature, as it is considered to be one of the main species indicative of allelopathic activity, by rapid and uniform germination (Wandscheer and Pastorini, 2008). Therefore, considering the result of the control treatment and the distilled water (Table 1), the germination of the recipient species was 100%, demonstrating the validity of the comparison of results obtained with the application of the extracts.

In the composition of the plant material used in the preparation of the oat extracts evaluated in this study, a correlation analysis (data not shown) showed no association between the percentage of germination of the indicator plant and the percentage of stem, leaf, and panicle of each genotype tested. Although the leaf is the preferred structure for studies of allelopathic activity using crude extracts, other plant fractions, such as, roots, stems, flowers, pollen, and seeds, may be the source of allelochemicals, which are produced throughout the life cycle of the plant (Souza Filho et al., 2011), which validate the results obtained here. The use of material from flowering plants has been useful in this study, as oats, especially black oats, is cultivated for straw formation in the no-tillage system of successor crops, and thus, dried in the full flowering stage. In addition, the concentration of allelopathic substances in oats, such as, phenolic compounds and antioxidants, is higher during the stage of grain development (Alfieri and Redaelli, 2015). The use of plant material from oat plants in the full-flowering stage is adequate for the purpose of research. As for the effect on germination, although all genotypes are effectively allelopathic (≥ 50% inhibition), there is variation between them, depending on the concentration of the extract (Table 1).

Extracts from UPFPS Farroupilha, AF 12104, AF 1345 Ucraniana, and Agro Quaraí were the most heterotoxic except for the latter cultivar, regardless of the concentration used. For most genotypes, germination was significantly reduced with increasing concentration. The evaluation of the germination of indicator plants was done because extracts that had deleterious effects on the physiological and genetic aspects of the seeds interfered with the development and/or survival of the seedlings (Souza Filho and Mourão Jr., 2010; Wandscheer et al., 2011). The fact that a high allelopathic effect on germination was observed, even in the lower concentration of the extracted plant material, corroborates the allelopathic value of the oats, as generally, germination is less influenced by allelochemicals when considering its effect on the velocity of germination and seedling growth (Ferreira and Aquila, 2000).

All genotypes, except AF 12202-5%, were effectively allelopathic on GVI (Figure 1; Table 2). The extracts delayed germination, probably due to the change in the speed with which the seed absorbed water and triggered metabolic reactions of the reserves necessary for the survival of the seedling (Alves et al., 2015).

The primary root length is an essential attribute to evaluate the allelopathic activity of plant extracts, as the roots are more sensitive to the action of allelochemicals present in the extracts, when compared to the other structures of the seedlings (Chon et al., 2000). The *in vitro* allelopathic effect of different wheat cultivars inhibited root lengthening of rye grass seedlings ranging from 23.98% to 90.91%, as observed by Wu et al. (2000).

SBCPD

In the hypocotyl length, it was observed that in the extracts in which there was development of seedlings, they were classified as potentially allelopathic (35% to 49% inhibition), according to a criterion established by Souza Filho and Mourão Jr. (2010), except for AF 1345 Ucraniana and AF 12202, at 5% concentration (Figure 2 and Table 2). The fact that the attribute length of the primary root of the seedlings is affected by all extracts compared to the length of the hypocotyl is due to the pattern of response of each structure of the recipient species in relation to the inhibitory action of the allelochemicals present in the extracts (Abdelgaleil and Hashinaga, 2007; Gatti et al., 2010; Oliveira et al., 2012).

All oat genotypes completely inhibited germination, and consequently, in the other attributes. In the maximum concentration of the extract it can be inferred, that in natural conditions of cultivation, with an increase in the amount of biomass, there is a greater quantity of allelochemicals in the effluents from waste decomposition. The accumulation of the black oat biomass controls the density of Alexander grass (*Brachiaria plantaginea* (Link) Hitch) (Theisen et al., 2000) and other species (Brust and Gerhards, 2012), indicating an important suppressive effect of the invasives in agricultural systems. The use of this plant for forage production and soil cover can be an alternative for weed suppression, as well as protection and improvement of the physical and sanitary conditions of the soil (Santi et al., 2003).

Oat cultivation may influence soil conditions through the exudation of allelopathic substances, and intense straw formation may inhibit seed germination, which may also be influenced negatively by the decrease in the incidence of light on the soil (Theisen et al., 2000). This may be considered, because extracts from dry aerial part of oats cause significant deleterious effects on germination and elongation of the root of the seedling (Table 1 and Figure 2). Thus, the inhibition of seed germination, evidenced by the action of oat extracts (Table 1), may slow the process of formation of new weeds in the growing areas, reducing their competitive capacity by factors essential to their survival (Souza Filho and Mourão Jr., 2010).

The allelopathic activity of oats can be attributed, in part, to its ability to exude scopoletin (Jacobi and Fleck, 2000). However, oats are rich in other phenolic compounds, such as ferulic and p-coumaric acid, present in the cell walls of white oats and black oats, to which allelopathic effects are also attributed (Chini, 2017; Escobedo-Flores et al., 2018).

The allelochemicals present in oats are final or intermediate substances of the plant's secondary metabolism, biosynthesized from compounds originating from the primary metabolism. These substances are released to the environment by volatilization, leaching, decomposing plant tissue, or exudation of the root system (Wandscheer et al., 2011).

Oats are endowed with preformed structural substances, which constitute a physical and chemical defense barrier that restricts infection by pathogens. Lignin, suberin, and primary saponins avenacin A-1 and avenacosides A and B are examples of these compounds. The synthesis of these compounds in the plant occurs in greater intensity when it is attacked by phytopathogens (Soriano et al., 2004, Mert-Türk et al., 2005, 2006, Pecio et al., 2013). These substances may also be related to plant allelopathic activity.

The total inhibition of germination and root elongation by the oat extracts tested here challenge their phytochemical characterization, as plants that synthesize substances with allelopathic activity may have biocidal action and may be used as an alternative to pesticides, besides serving as possible sources of new compounds (Niro et al., 2016).

In this bioassay there was intra and inter-specific variability in white oats and black oats regarding plant allelopathic activity, to be manifested according to the amount of vegetal material used in the crude aqueous extracts. The inhibitory effect increases with the increase in the concentration of extract, which results in a higher accumulation of allelochemicals, which are compounds responsible for the deleterious effects on seeds and seedlings of the recipient species.

The genotypic effect in the *Avena* spp. with regard to the allelopathic potential may be a promising field of study in breeding programs. Furthermore, the use of functional descriptors related to allelopathy and to the allelochemical composition in the breeding programs of *Avena* spp. would add important information to the strategy of using the crop as a cover crop, rotation crop, and in straw production, contributing to the suppression of weeds.

The genotypic difference was better evidenced at 5% concentration, and in the descending order of effective allelopathic action on root and hypocotyl germination and elongation (inhibition > 50%), extracts of UPFPS extracts Farroupilha > AF 12104 > AF 1345 Ucraniana > Agro Quaraí > Embrapa 139 > AF 12109 > AF 12209 > Agro Esteio > AF 12202.

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