COMMUNICATIONS IN PLANT SCIENCES

Differential influence of shoot extracts of winter cover crops on seed germination of corn, soybean and indicator plants

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The objective was to test the response of summer crops (*Zea mays* and *Glycine max*) and indicator plants to exposure to extracts of winter cover crops (*Avena sativa*, *Lolium multiflorum* and *Triticum aestivum*) regarding on seed germination. Bioassays were carried out to test six shoot extract concentrations, by using germitest paper maintained in controlled conditions. *Zea mays*, *Glycine max*, *Lactuca sativa* and *Phalaris canariensis* showed differential response to exposure to shoot extracts of *Avena sativa*, *Lolium multiflorum* and *Triticum aestivum* regarding on seed germination. Shoot extracts of *Avena sativa* and *Lolium multiflorum* increased seed germination while shoot extract of *Triticum aestivum* reduced seed germination of *Zea mays*. Shoot extracts of *Avena sativa*, *Lolium multiflorum* and *Triticum aestivum* reduced seed germination of *Glycine max*, *Lactuca sativa* and *Phalaris canariensis*.

Highlighted Conclusion
Winter cover crops can show different allelopathic potential on summer crops.

Cover crops (e.g. winter crops) have several beneficial effects on agricultural fields (Kunz et al. 2016), including the weed suppression (Brust et al. 2014, Jabran et al. 2015) provided, among other reasons, by the release of allelopathic substances from cover crops and/or crop residues (Farooq et al. 2011) into the soil via leachates or root exudates, or by decomposition of plant biomass (Bonanomi et al. 2006). The allelopathic substances (e.g. phenolics, flavonoids or terpenoids – Macías et al. 2007), that can be synthesized in leaves, fruits, roots or seeds (Radosevich et al. 2007), may influence weed seed germination (Kunz et al. 2016) and/or inhibit weed plant growth (Farooq et al. 2011). However, the inhibitory effects may also influence, in different ways and intensities, on the subsequent summer crop (as reviewed by Shah et al. 2016).

In the Southwest of Brazil, oat (*Avena sativa*) and wheat (*Triticum aestivum*) are commonly cropped as winter crops, and ryegrass (*Lolium multiflorum*) is normally used as a winter pasture. So, these species can be considered as winter cover crops preceding summer crop seeding. Summer crops, such as corn (*Zea mays*) and soybean (*Glycine max*), are commonly seeded into straw residues of winter cover crops. Thus, we hypothesized that winter cover crops can show differential allelopathic potential on subsequent summer crops (in a crop rotation system). The objective was to test the response of summer crops to exposure to extracts of winter cover crops regarding on seed germination.

MATERIAL AND METHODS

An experiment was carried out to test the allelopathic potential of shoot extracts of oat, ryegrass and wheat, winter cover crops, on seed germination of corn, soybean – summer crops – lettuce (*Lactuca sativa*) and birdseed (*Phalaris canariensis*) – indicator crops. Bioassays were conducted using germitest papers soaked with distilled water and five concentrations of shoot extracts of each winter cover crop [2.5 times in relation to paper mass, according to Brasil (2009)]. Fifty seeds (replicated four times) of summer and indicator crops were placed into three soaked leaves of germitest paper, and them the paper was rolled and placed in a BOD at 25 ^{o}C temperature, 14h-10h photoperiod (light-dark), and 60% relative humidity.

Winter cover crops were previously cultivated in 7-L pots until the flowering stage when shoot parts were cut off to prepare the extracts. Fresh shoot material was weighted (0.2, 2, 5, 10, and 20 g) and crushed with 200-mL distilled water. The solutions were filtered to obtain the shoot extracts with concentrations by 1, 10, 25, 50, and 100 g L^{-1}.

The number of germinated seeds was counted at 7 days after being placed in the BOD. A germinated seed was considered if the tegument was ruptured due to radical protrusion (as used by Basu et al. 2016).

Germination data were previously analyzed by Kolmogorov-Smirnov normality test and Levene homogeneity of variances test ($P=0.05$). We verified normal distribution of residues and homogeneity of variances, so that germination data were further analyzed by ANOVA (F test – $P=0.05$), considering a factorial design 3x6x4 (three winter cover crops, six extract concentrations and four crops). The interaction among the three factors was significant ($P<0.05$), and them we proceeded with the unfolding of degrees of freedom considering a polynomial regression for extract concentrations. No regression model was highly significant ($P<0.10$ and $R^2>0.90$), so that we decided to proceed with an exploratory grouping analyze, using a clustering method with the Single Linkage as the Algamation Rule and the Euclidean Distances as the Distance metric.

RESULTS

Germination of corn increased when seeds were soaked with shoot extracts of oat and ryegrass, however it reduced when shoot extract of wheat was used (Figure 1). In addition, germination of soybean, lettuce and birdseed decreased when seeds were soaked with shoot extracts of oat, ryegrass and wheat (Figure 1). In general, birdseed germination was more influenced by shoot extracts, followed by lettuce, both indicator crops (Figure 1). In spite of no improvement on seed germination, the negative impact of the winter cover crops on soybean was not highly significant (Figure 1). So, indicator crops were more susceptible to shoot extracts of winter cover crops then summer crops, and corn and soybean showed differential response on seed germination due to exposure to shoot extracts of winter cover crops (Figure 1).

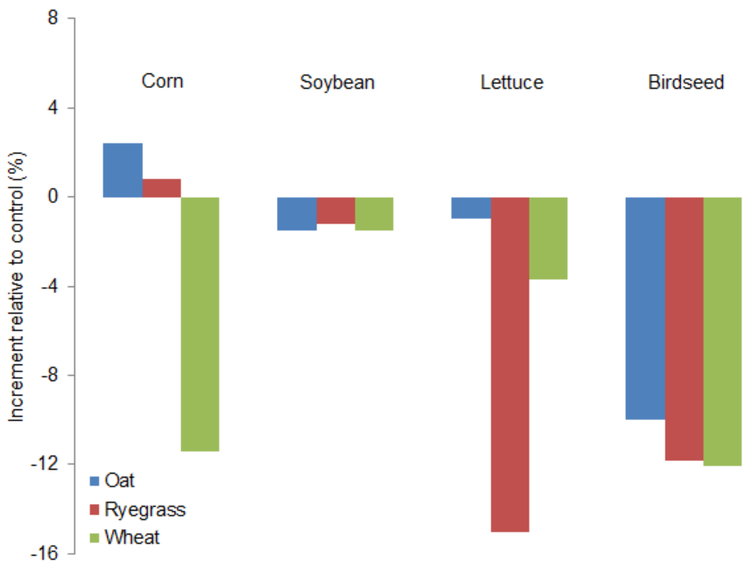

Figure 1. Increment of germination of crops (corn, soybean, lettuce and birdseed) at 7 days after maintaining seeds soaked in extracts (mean of six concentrations varying from 1 up to 100 g L^{-1}) of shoot of winter cover crops (oat, ryegrass and wheat).

Grouping analysis evidenced similar response of lettuce and birdseed for all winter cover crops (Figure 2). In addition, similar response of corn and soybean was observed for oat and ryegrass (Figure 2). However, soybean response to extract of wheat was closer to the indicator crops than the corn (Figure 2). Moreover, for soybean and lettuce, effects of oat and wheat were grouped, differently of the effect of oat and ryegrass for corn and the effect of ryegrass and wheat for birdseed (Figure 3).

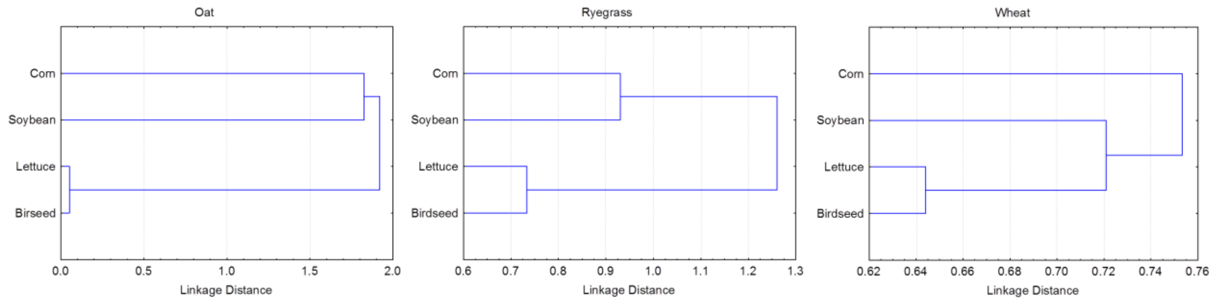

Figure 2. Exploratory analysis for grouping crops (corn, soybean, lettuce and birdseed) based on germination (%) at 7 days after maintaining seeds soaked in extracts (mean of six concentrations varying from 1 up to 100 g L^{-1}) of shoot of winter cover crops (oat, ryegrass and wheat).

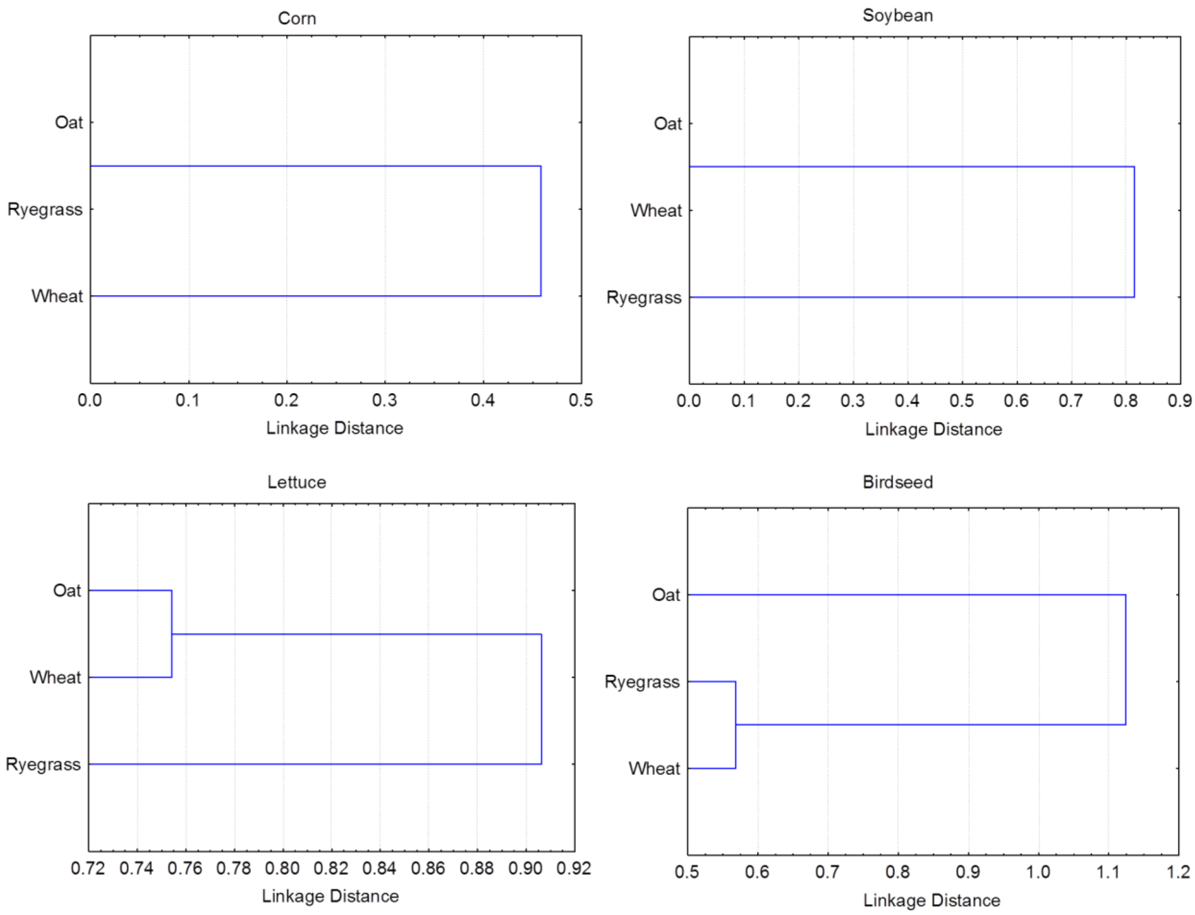

Figure 3. Exploratory analysis for grouping winter cover crops (oat, ryegrass and wheat) on crops (corn, soybean, lettuce and birdseed) based on the effect on crop germination (%) at 7 days after maintaining seeds soaked in extracts (mean of six concentrations varying from 1 up to 100 g L^{-1}) of shoot of winter cover crops.

DISCUSSION

Inhibitory role of allelopathic substances is well explored and previously was the only known dimension of allelopathy; this inhibitory feature is attributed to the blockage or cessation of important physiological and metabolic processes of plant (Farooq et al. 2013). On the other hand, allelopathic substances promote seed germination and/or plant growth (Farooq et al. 2009 a,b). For example, allelopathic water extracts application, as used in this study, stimulates germination and growth of different crops (Anwar et al. 2003, Cheema et al. 2012), similarly to observed by us. Stimulatory effects of allelopathic substances can be provided by mechanisms of physiological regulation, hormonal balance and enzyme activity (Farooq et al. 2013). In this study, inhibitory effects was prevalent for wheat extracts, indicating if we cultivate corn or soybean after wheat, crop seed germination can be reduced due to allelopathic substances released into the soil.

In a crop rotation system, the role of winter cover crops on weed suppression and management is well known. When winter cover crops are managed and combined with reduced tillage practices, the straw residue suppresses weeds (den Hollander et al. 2007, Lawley et al. 2012) and also allelopathic substances can be released into the soil, reducing weed germination and growth (Kunz et al. 2016). Agronomical practices preventing weed emergence and growth may reduce subsequent weed seed rain and dispersion, resulting in long-term weed suppression (Mirsky et al. 2010). However, some negative effects of cover crops on yield of subsequent crops have been documented in crop rotation systems (Creamer et al. 1996, Dhima et al. 2006, Marcillo and Miguez 2017), being a part of these effects caused by releasing allelopathic substances into the soil (Kunz et al. 2016).

Side effects of cover crops may occur, such as delay germination and planting owing due to excess soil moisture, enhance the nitrogen immobilization, and damaging effects of allelopathic substances on major crops (Ashraf et al. 2017). However, the impact of allelopathic substances on crops is dependent on the behavior of these compounds in the soil; so that, after being released into the soil, allelopathic substances need to attain the target plants to impact them (Trezzi et al. 2016). In addition, the characteristics of these compounds play an important role in their fate in the field (Trezzi et al. 2016), so that the water soluble substances might moves easily within the soil (Souza Filho and Alves 2002). The sorption and degradation mechanisms are also important to drive the behavior of these compounds in the soil and their effects on other crops. As a consequence, allelopathic substances can reach subsequent crops in a crop rotation system (Alsaadawi 2001).

In this way, Martin et al. (1990) observed that the straw of ryegrass releases allelopathic substances that can inhibit 34% corn root growth. Chovancová et al. (2015) also observed allelopathic potential of cover crops on corn. Yassen and Hussain (2014) verified allelopathic effects of wheat on rice. The inhibition of cover crops on germination of spring barley was reported (Marcinkevičiene et al. 2013). In addition, allelopathic potential of winter cover crops was reported against major crops and weeds (Kunz et al. 2016, Trezzi et al. 2016). On the other hand, highest maize yields cropped after cover crops were reported (Prochazka and Prochazkova 2012). Thus, we have to be avoided through the selection of optimized integrated cover crops with good management practices in cropping system (Ashraf et al. 2017).

CONCLUSION

Corn, soybean, lettuce and birdseed show differential response to exposure to shoot extracts of oat, ryegrass and wheat regarding on seed germination. Shoot extracts of oat and ryegrass can improve seed germination while shoot extract of wheat can reduce seed germination of corn. Shoot extracts of oat, ryegrass and wheat can reduce seed germination of soybean, lettuce and birdseed.

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