SOIL MOISTURE ON EMERGENCE AND INITIAL DEVELOPMENT OF *Bidens pilosa*†

[HUMEDAD DEL SUELO EN LA EMERGENCIA Y DESARROLLO INICIAL DE *Bidens pilosa*]

Márcia Maria Mauli[1]*, Lúcia Helena Pereira Nóbrega[1], Antonio Pedro Souza Filho[2], Adriana Maria Meneghetti[3], Danielle Medina Rosa[1] and Michelle Tonini[1]

[1] Universidade Estadual do Oeste do Paraná- UNIOESTE – Cascavel – PR, Brazil. Email: marcia.m.mauli@gmail.com
[2]EMBRAPA Amazônia Oriental – Belém – PA, Brazil
[3]Universidade Tecnologica Federal do Paraná – UTFPR – Santa Helena – PR, Brazil
**Corresponding author*

SUMMARY

Some species are used as cover crops, so they can produce and release products from their secondary metabolism. When these products are released in the environment, they are exposed to direct or indirect influences. Thus, this trial aimed to evaluate the influence of soil moisture content in plant decomposition, possibly caused by allelochemicals release. The influence of soil field capacity was evaluated by the decomposition of black oats (*Avena strigosa* Schreb), turnip (*Vicia villosa* Roth) and hairy vetch (*Raphanus sativus* L.) residues, with 70 and 50% of water availability and the control. Pots (1.0 kg) were filled with sterilized and unsterilized soil, plus 30 g of plant residue, which remained in decomposition for four weeks before the experiment start. After that, five seeds of beggartick (*Bidens pilosa* L.) were sowed and seedling emergence was daily evaluated for 10 d. The emergence speed index and emergence speed were calculated. Five seedlings were transplanted at the 8th d and evaluated during 30 d, to obtain the initial development of plants, and to determine fresh and dry mass. Greatest growth inhibition of the weed tested occurred with 70% available water for plant emergence and with 50% for initial plant development.
Keywords: allelochemicals; available water on soil; cover crops; weeds.

RESUMEN

Algunas especies de plantas utilizadas como cobertura son capaces de producir y liberar productos del metabolismo secundario, que cuando están en el ambiente, pueden sufrir la influencia directa o indirecta de un conjunto de factores. Así, el objetivo de este trabajo fue evaluar la influencia de la humedad del suelo en la descomposición del material vegetal, posiblemente ocasionada por la liberación de aleloquímicos. Se evaluó la influencia de la capacidad de campo en la descomposición de los residuos de avena negra (*Avena strigosa* Schreb), nabo forrajero (*Vicia villosa* Roth) y guisante peludo (*Raphanus sativus* L.), con 70 y 50% de disponibilidad de agua, más el testigo (100%). Se llenaron macetas de 1.0 kg de capacidad con suelo esterilizado y no esterilizado, más 30 g de material vegetal, el cual permaneció en descomposición por cuatro semanas antes de iniciar con el experimento. Después de ese período, se sembraron cinco semillas de aceitillo (*Bidens pilosa* L.) y se evaluó diariamente la emergencia de las plántulas durante 10 d. Se calculó el índice de velocidad de emergencia y la velocidad de emergencia. Se trasplantaron cinco plántulas en el 8º d, y se evaluaron durante 30 d para obtener el desarrollo inicial de plantas, y determinar el peso fresco y seco. Las mayores inhibiciones en la maleza evaluada ocurrieron con el 70% del agua disponible para la emergencia de la planta y con el 50% para el desarrollo inicial de planta.
Palabras clave: aleloquímicos; disponibilidad de agua en el suelo; cultivo de cobertura; malezas.

† S*ubmitted April 28, 2016 – Accepted May 01, 2018.*

INTRODUCTION

The correct species choice of cover crops in different systems of regional production has been an important practice. Such heterogeneity contributes to greater biodiversity and therefore, creates more favorable conditions for the development of many natural enemies and environment balance for both, amount of organisms and soil nutrients. These are ideal conditions for crop development and yield (Colozzi and Andrade, 2006; Rains *et al*., 2011; Embrapa, 2004; Silva, 2012). In addition, many plants used as cover crops have chemical compounds that, when released into the environment, may affect the growth and development of other organisms around. This interference is known as allelopathy (Rice, 1974). The use of plants with proven allelopathic properties is a promising alternative in agriculture, specially to control weeds in trading crops. Cover crops management has significantly reduced the intensity of weed infestation, as well as changed the composition of local weeds (Silva, 2012; Nunes *et al*., 2014; Mauli *et al*., 2015; Martins *et al*., 2016). When cover crops are used correctly, they can improve physical, chemical and biological properties of the soil, and the use of herbicides can be reduced or even eliminated. Although this is a promising alternative for weed control, it has not been adequately studied (Silva, 2012).

Each species has a specific ability to produce allelopathic substances, as well as its chemical nature, concentration, and susceptibility to allelochemicals that are released by other plants (Ferreira *et al.*, 2000; Bonanomi *et al*., 2006). These substances may act indirectly or directly. When acting indirectly, changes occur in soil properties, nutritional conditions, variation of microorganism populations and their activity. When the action is direct, the substances act on membranes of the target plant. Therefore, they allow both bonding and penetration of compounds into cells, and thus interfere on their metabolism (Seigler, 2006).

In the soil, chemical compounds can strongly interact with colloids and suffer microbial transformations responsible for deactivation or degradation (Colozzi and Andrade, 2006). However, the decomposition of these substances is slower in a sterile soil, which highlights the involvement of microorganisms in the process. The phytotoxic potential is controlled by microbial activity, responsible for transformations and degradation of active forms, or even their activation in soil. Although some steps are abiotic, the participation of microorganisms is evident and essential for the dynamics and activity of several substances in soil. Some substances must be transformed to act as allelochemicals (Pedrol *et al.*, 2006; Colozzi and Andrade, 2006). Several microorganisms are specialized to convert, synthesize, eliminate, or use secondary metabolites as a source of carbon and energy. At the same time, microorganisms release bioactive compounds from wastes in decomposition and contribute to eliminate these natural toxins from the soil through decomposition. Allelochemicals can be immobilized during solid phase; they establish equilibrium with the soil solution and may suffer degradation or even leach, especially in sandy soils (Moreira and Siqueira, 2006). Understanding the occurrence, activity and/or behavior of microorganisms and natural compounds in processes influenced by soil moisture can support the background to design more efficient crop rotation systems with these residues (Pedrol *et al*., 2006; Souza Filho, 2006; Mauli *et al*., 2011). Some species, such as black oats (*Avena strigosa* Schreb), turnip (*Vicia villosa* Roth) and hairy vetch (*Raphanus sativus* L.) are already used as cover crops, with reports of potentially allelopathic activity on weeds when used in crop rotation. These species have allelopathic potential that can act on germination and/or development of other plants, affecting the affected organism in several ways, such as reducing photosynthesis, protein synthesis, membrane permeability and inhibition of enzymatic activity, among several others (Santos and Reis, 2003; Embrapa, 2004; Weih *et al*., 2008, Rains *et al*., 2011). Thus, the objective of this study was to evaluate the influence of soil water availability on the decomposition of black oats (*Avena strigosa* Schreb), turnip (*Vicia villosa* Roth) and hairy vetch (*Raphanus sativus* L.), cover crops already used in some regions, and the initial germination and development of *Bidens pilosa* L.

MATERIAL AND METHODS

To verify the effect of plant residue decomposition on *B. pilosa*, an assay was established in a greenhouse to test two water availability levels (70 and 50%) in soil. Initially, the capacity of water retention in pots was determined according to Ruiz *et al.* (2003) methodology. Pots of 1.0 kg capacity were filled up with soil from cropping land at 0 to 20 cm-depth in Catanduvas city, Paraná (chemical characteristics shown in Table 1); soil was sieved and air-dried. Pots were watered and kept at 70 and 50% of available water; control treatment received 100% of available water. Soil was covered with 30 g of dry mass of the following cover crops: Black oats (*A. strigosa*), turnip (*V. villosa*) and hairy vetch (*R. sativus*). The soil with leaves on top mulch were decomposed for four weeks in a greenhouse with an average temperature of 26 °C. After this period, five seeds of beggartick (*B. pilosa*) were sowed and seedling emergence was evaluated daily for 10 d. Emerged seedlings were selected and the emergence rate speed (ERS), that is, number of plants emerge d^{-1} (Maguire, 1962) and emergence speed (ES), or number of days that took seedlings to emerge, were also calculated (Edmond and Drapalla, 1958). Five beggartick seedlings 8 d old were transplanted to evaluate their initial development. They were submitted to the same experimental conditions of emergence test described above, and were evaluated for 30 d. Then, each plant was separated in roots and shoots, weighed on a 0.001-g precision scale and taken to the oven at 65 °C until constant weight, to quantify dry mass. To check for microorganisms' activity, during emergence and initial development, a sterilized and non-sterilized soil were used. Pots were daily weighted, adding the amount of water required for each test.

Data was submitted to analysis of variance. Means were compared by Tukey tests at 5% probability. Initially, data normality and homogeneity of variances were verified. Transformations were carried out according to Pimentel (2000), and Banzatto and Kronka (2006) with Minitab® 14 and SISVAR software (Ferreira, 2008). Data in percentage were transformed into $arcsen\sqrt{\frac{x}{100}}$, and those that showed a non-normal distribution were submitted to $\sqrt{x}$, as necessary.

Tabla 1. Chemical characteristics of the soil used in the experiment, taken from a depth of 0-20 cm. Catanduvas – PR, Brazil (2011).

Characteristics of soil*	Values	Classification**
pH ($CaCl_2$)	5.5	Medium
Organic matter (g dm^3)	54.95	Very high
Exchangeable aluminum ($cmol_c$ dm^3)	0.00	Very low
Potential acidity ($cmol_c$ dm^3)	4.28	-
Base sum ($cmol_c$ dm^3)	16.34	High
Cation exchange capacity ($cmol_c$ dm^3)	20.62	High
Base saturation (%)	79.24	High
P ($cmol_c$ dm^3)	21.40	Very high
K ($cmol_c$ dm^3)	1.14	Very high
Ca ($cmol_c$ dm^3)	12.25	High
Mg ($cmol_c$ dm^3)	2.95	High
Cu (mg/dm^3)	13.77	High
Zn (mg/dm^3)	18.32	High
Fe (mg/dm^3)	36.00	Medium
Mn (mg/dm^3)	351.00	High

* Analysis performed in the Soils Laboratory of the Cooperativa Central de Pesquisa Agrícola (COODETEC).
** Classification according to Alvarez *et al*. (1999).

RESULTS AND DISCUSSION

Values for beggartick seedlings emergence, submitted to 70 and 50% of water availability in sterilized soil are shown on Table 2.

The emergence inhibition percentage of beggartick was significant on black oats and hairy vetch. In both residues, inhibition at 70% water availability was higher than at 50%. However, on black oats, this result was superior to 85%. Concerning turnip, there was no significant difference.

The rate of emergence was significant for the three species studied, and presented a lower rate when submitted to 70 and 50% in relation to the control. However, when we compared 70 with 50%, the data did not differ statistically from each other. This means that the number of emergent seedlings per day decreased when there was more water availability in the soil, as observed in the control (100%).

The emergence speed was significant for black oats and hairy vetch plant residues. The ES was lower under 70% water availability when submitted to black oats, but, when analyzed at 50% and compared to the control, there were no significant differences. For hairy vetch residues, 70 and 50% of water availability had lower ES when compared to control, but did not present statistical difference between them. Thus, seedlings submitted to black oats at 70% water availability and hairy vetch at 70 and 50% took more days to emerge than those ones at 100% water availability (Table 1). The lowest water availability in soil may have resulted in higher allelochemical concentrations, and consequently, it might promote greater influence on the beggartick emergence. One advantage of this delay in weeds emergence is the increased period of time to control them properly. This would make the operation more efficient under field conditions (Moraes *et al*., 2011).

The values of seedling emergence in beggartick at 70 and 50% water availability, in a not sterilized soil are shown in Table 3. The beggartick inhibition percentage was significant for black oats and presented data with regular dispersion. However, at 70% water availability there was 85.69% inhibition that differed from 50% water availability. For turnip and hairy vetch plant residues, there was no significant difference.

The emergence speed index for seedlings of beggartick was significant on unsterilized soil for the three plants residues studied. The number of seedlings emerged per day showed similar behavior in black oats and turnip, however, the response to 50, 70 and 100% (control) water availability showed different behaviors among themselves. At 70% water availability, the lowest emergence speed index was recorded. For the hairy vetch, there was a significant difference among the control and 70 and 50% water availability, being the last two with the lowest emergence speed index values, but they did not differ among themselves.

The emergence speed of berggartick seedlings on unsterilized soil was significantly different for black oats, turnip and hairy vetch plant residues. The beggartick seedling emergence speed showed the same behavior for the three plant residues, however, significant differences were shown with each treatment and the control, and between both treatments, where 70% the emergence speed showed the lowest value.

Based on the results, the greatest emergence inhibition of beggartick seedlings occurs at 70% water availability in soil. As a hypothesis, this may be associated to the presence and activity of organisms, which are conditioned by physical (mineralogy, moisture, aeration and temperature) and chemical (pH and fertility) components of soil. For example, when the soil is dry, the bacteria reduce their activity or stay under dormancy for some time (Colozzi and Andrade, 2006; Moreira and Siqueira, 2006), consequently, allelochemicals could have been retained in soil particles, since the phytotoxic potential is controlled by microbial activity, responsible for transformation and degradation of active forms or even their activation (Pedrol *et al.*, 2006; Colozzi and Andrade, 2006).

Table 2. Percentage of emergence inhibition, emergence speed index (ESI) and emergence speed (ES) of beggartick seedlings submitted to plant residue of black oat, turnip and hairy vetch, at 70 and 50% of water availability in sterilized soil.

Water availability	Black oats	Turnip	Hairy vetch
	Emergence inhibition (%)		
70%	85.69 a	67.00a	57.08 a
50%	49.92 b	64.23a	55.41 b
Mean	67.91	65.61	56.24
Coefficient of Variation	7.11	11.57	1.73
F value	25.00 *	0.33 n.s.	26.00 *
	Emergence speed index (seedlings per day)		
Control	0.81 a	0.80 a	0.82 a
70%	0.11 b	0.24 b	0.29 b
50%	0.36 b	0.22 b	0.37 b
Mean	0.42	0.43	0.48
Coefficient of Variation	5.63	19.86	18.31
F value	41.87 *	48.82 *	28.96 *
	Emergence speed (days)		
Control	0.80 a	0.81a	0.81 a
70%	0.16 b	0.44a	0.50 b
50%	0.55 a	0.45a	0.41 b
Mean	0.50	0.54	0.58
Coefficient of Variation	27.48	9.46	10.98
F value	16.69 *	3.61 n.s	32.95 *

Means followed by different letters in the same column, differ by Tukey test ($p \leq 0.05$).
n.s.= no significant, * = Significant.

Table 3. Emergence inhibition percentage, emergence speed index (ESI) and emergence speed (ES) of beggartick seedlings under plant residues of black oats, turnip and hairy vetch, at 70 and 50% water availability in unsterilized soil

Water availability	Black oats	Turnip	Hairy vetch
Emergence Inhibition Percentage			
70%	85.69 a	78.54 a	71.37 a
50%	57.08 b	58.00 b	49.92 b
Mean	71.39	67.81	60.66
Coefficient Variation	12.27	22.38	25.02
F value	16.00 *	13.00 *	13.99 *
Emergence Speed Index (seedlings per day)			
Control	0.89 a	0.88 a	0.89 a
70%	0.11 c	0.16 c	0.23 b
50%	0.27 b	0.37 b	0.25 b
Mean	0.43	0.47	0.42
Coefficient Variation	15.04	24.02	28.37
F value	124.08 *	32.72 *	24.82 *
Emergence Speed (Days)			
Control	0.89 a	0.89 a	0.89 a
70%	0.17 c	0.24 c	0.29 c
50%	0.51 b	0.53 b	0.50 b
Mean	0.52	0.55	0.57
Coefficient Variation	9.84	15.46	12.30
F value	10.82 *	42.42 *	4.35 *

Means followed by different letters in the same column, differ by Tukey test ($p \leq 0.05$). * = Significant.

Soil sterility (sterilized soil) did not show major differences in this case, except for turnip, with greater effects in unsterilized soil, which could be explained by studies related to the sensitivity to the presence of microorganisms in the soil.

The obtained values for the initial development of beggartick in plant residues of black oats, turnip and hairy vetch at 70 and 50% water availability, in sterilized soil, are shown in Table 4. The three studied plant residues influence significantly on beggartick shoot fresh mass (SFM). In all residues, 70 and 50% of water availability differed from the control and presented the lowest fresh mass. However, 70 and 50% water availability showed similar results. Root fresh mass was significantly different in treatments with turnip and hairy vetch residues. The turnip, submitted to 70 and 50% water availability, was significantly different from the control, but not at each level of water availability. The hairy vetch, under 50% water availability, differed from the control, however, under 70% did not differ from the control nor under 50% water availability.

Shoot dry mass showed significant changes under black oats and turnip residues, with significant differences under 70 and 50% water availability compared to the control. However, both water availability levels did not differ between them. With hairy vetch residues, both treatments and the control differed among themselves, however, the 50% water availability treatment showed the lowest shoot dry mass.

Root dry mass showed significant changes under the studied plant residues. On black oats residues, root dry mass at 70% water availability differed from the control and showed the lowest value. However, it did not differ from the 50% treatment, which also did not differ from the control. Turnip residues, under 70 and 50% water availability treatments, differed from the control and showed the lowest root dry mass. But both water availability levels did not differ significantly from each other. Root dry mass under hairy vetch, at 50% water availability differed from the control and showed the lowest root dry mass, but it did not differ from the 70% water availability level, and was not significantly different from the control. The use of this possible allelopathic activity stands out as an alternative to complement the chemical control in suppressing weeds in the agro-ecosystem (Weih *et al*., 2008).

On Table 5, the values for the initial plant growth of beggartick are presented at 70 and 50% water availability in an unsterilized soil.

Table 4. Fresh and dry mass of shoot and root beggartick plants (g plant^{-1}) grown in soil mixed with black oats, turnip and hairy vetch plant residues, at 70 and 50% water availability in sterilized soil.

Water availability	Black Oats	Turnip	Hairy Vetch
Shoot fresh mass (g plant^{-1})			
Control	0.77 a	0.77 a	0.77 a
70%	0.47 b	0.33 b	0.45 b
50%	0.60 b	0.47 b	0.20 b
Mean	0.61	0.52	0.47
Coefficient Variation	14.20	13.25	22.27
F value	8.85 *	30.54 *	21.92 *
Root fresh mass (g plant^{-1})			
Control	0.24 a	0.24 a	0.24 a
70%	0.11 a	0.07 b	0.13 ab
50%	0.13 a	0.06 b	0.04 b
Mean	0.16	0.12	0.13
Coefficient Variation	33.58	25.64	38.85
F value	5.29 $^{\text{not significant}}$	32.40 *	10.67 *
Shoot dry mass (g plant^{-1})			
Control	0.20 a	0.20 a	0.20 a
70%	0.10 b	0.06 b	0.10 b
50%	0.12 b	0.10 b	0.06 c
Mean	0.14	0.12	0.12
Coefficient Variation	17.76	9.83	3.31
F value	13.08 *	100.00 *	78.00 *
Root dry mass (g plant^{-1})			
Control	0.16 a	0.16 a	0.16 a
70%	0.05 b	0.04 b	0.08 ab
50%	0.08 ab	0.06 b	0.03 b
Mean	0.10	0.08	0.09
Coefficient Variation	35.35	38.27	35.27
F value	8.09 *	14.59 *	13.13 *

Means followed by different letters in the same column, differ by Tukey test ($p \leq 0.05$). * = Significant.

Shoot fresh mass of beggartick plants in an unsterilized soil, under black oats residues, presented significantly difference from the control and treatments of 50 and 70% water availability, with lower mass, but with no significant differences between residue treatments. The water availability treatments and control differed among themselves under turnip residues, but at 50%, it was observed the lowest shoot fresh mass. With hairy vetch residues, 50% water availability differed from the control and showed the lowest shoot fresh mass, however, it did not differ from 70%, and also it did not differ from the control.

Root fresh mass differed among the cover crops residues. The lowest mass values were observed under black oats and turnip residues, and 70 and 50% water availability differed from the control, but they did not differ from each plant residue. The 50% water availability treatment differed from the control and showed the lowest mass under hairy vetch residues, however, it did not differ from the 70% water availability treatment, and it also did not differ from the control.

Shoot dry mass differed in the three analyzed residues. Results showed some similarity in black oats, turnip and hairy vetch. The 70 and 50% water availability treatments presented lower mass values when compared to the control, however, both treatments were not significantly different. Root dry mass showed significant changes only in black oats, with low data homogeneity; however, 70 and 50% water availability treatments were not significantly different. The probable effects caused by allelochemicals release might be useful in crop rotation or intercropping, in the context of integrated management of weeds (Erasmo *et al*., 2004). However, further studies are needed to indicate a reduction of specific allelochemicals produced by a precise group of microorganisms, in order to elucidate these results.

Table 5. Fresh and dry mass of shoot and root beggartick plants (g per plant^{-1}) grown in soil mixed with black oats, turnip and hairy vetch plant residues, at 70 and 50% water availability in an unsterilized soil.

Water availability	Black oats	Turnip	Hairy vetch
Shoot fresh mass (g plant^{-1})			
Control	0.77 a	0.77 a	0.77 a
70%	0.26 b	0.40 b	0.32 ab
50%	0.34 b	0.07 c	0.13 b
Mean	0.45	0.41	0.41
Coefficient Variation	24.37	16.86	37.90
F value	17.97 *	73.83 *	13.05 *
Root fresh mass (g plant^{-1})			
Control	0.24 a	0.24 a	0.24 a
70%	0.09 b	0.10 b	0.06 ab
50%	0.08 b	0.07 b	0.13 b
Mean	0.13	0.14	0.14
Coefficient Variation	20.88	17.50	33.86
F value	30.29 *	41.16 *	10.31 *
Shoot dry mass (g plant^{-1})			
Control	0.20 a	0.20 a	0.20 a
70%	0.05 b	0.09 b	0.06 b
50%	0.07 b	0.05 b	0.05 b
Mean	0.10	0.11	0.10
Coefficient Variation	9.37	13.09	19.14
F value	99.00 *	71.28 *	47.36 *
Root dry mass (g plant^{-1})			
Control	0.16	0.16 a	0.16 a
70%	0.04 b	0.07 a	0.08 a
50%	0.06 b	0.08 a	0.09 a
Mean	0.09	0.10	0.10
Coefficient Variation	35.35	37.69	38.45
F value	8.94 *	5.95 not significant	6.39 not significant

Means followed by different letters in the same column, differ by Tukey test ($p \leq 0.05$). * = Significant.

Soil sterilization did not have a significant influence in this trial. The cause of variation was the available water in soil. This may have occurred because the pot with plant material remained for four weeks to be decomposed; this period, determined in previous evaluations, may have provided a favorable environment for microorganisms' development (Unpublished data). Probably, when beggartick seeds or seedlings were added, microorganisms might have been already present in both cases, sterilized and non-sterile soil. This could provide similar results in relation to the decomposition of plant residues and, consequently, the release of allelochemicals.

Thus, cover crops could be managed during rainy season, since soil water content might influence directly the activity of microorganisms on allelochemicals activation and thus it could increase the inhibitory effects on beggartick. However, more studies need to be done about the microorganisms present in the soil and how these cover plants can act on them.

CONCLUSIONS

Seventy percent water availability promoted the decomposition of plant residues of black oats, turnips and hairy vetch plants left on top mulch soil, and that caused greater inhibitions of emergence and the early development of beggartick weed (*Bidens pilosa*).

REFERENCES

Banzatto, D.A., Kronka, S. Do N. 2006. Experimentação Agrícola. FUNEP. 4 ed., Jaboticabal, Brazil. 237 p.

Bonanomi, G., Sicurezza, M.G., Caporaso, S., Esposito, S., and Mozzoleni, S. 2006. Phytotoxicity dynamics of decaying plant materials. New Phytologist 169: 571-578.

Colozzi F., A., Andrade, D.S. 2006. Organismos do solo e atividade microbiana no plantio direto. Cap. 4. p. 39-53. *In:* Casão J., R. Siqueira, R., Mehta, Y. R., Passini, J.J. Sistema Plantio Direto com Qualidade. IAPAR, ITAIPU, Binacional, Londrina, Brazil. 212 p.

Edmond, J.B., and Drapalla, W.J. 1958. The effects of temperature, sand and soil, and acetone on germination of okra seed. Proceedings of the American Society for Horticultural Science 71: 428-443.

EMBRAPA (Empresa Brasileira De Pesquisa Agropecuária). 2004. Tecnologia da Produção de Soja – Paraná 2005. 1ª ed. Londrina: Embrapa Soja, 239 p.

Erasmo, E.A.L., Azevedo, W.R., Sarmento, R.A., Cunha, A.M., Garcia, S.L.R. 2004. Potencial de espécies utilizadas como adubo verde no manejo integrado de plantas daninhas. Planta Daninha 22: 337-342.

Ferreira, D.F. 2008. Sisvar: um programa para análise e ensino de estatística. Revista Científica Symposium 6: 6-41.

Ferreira, T.N., Schwartz, R.A., Streck, E.V. 2000. Solos: manejo integrado e ecológico – elementos básicos. EMATER/RS, Porto Alegre: Brazil. 95 p.

Maguire, J.D. 1962. Seeds of germination-aid selection and evaluation seedling emergence and vigor. Crop Science 2: 176-177.

Martins, D., Gonçalves, C.G., Silva Junior, A.C. 2016. Coberturas mortas de inverno e controle químico sobre plantas daninhas na cultura do milho. Revista Ciência Agronômica 47: 649-657.

Mauli, M.M., Nóbrega, L.H.P., Rosa, D.M., Lima, G.P. and Ralish, R. 2011. Variation on the Amount of Winter Cover Crops Residues on Weeds Incidence and Soil Seed Bank during an Agricultural Year. Brazilian Archives of Biology and Technology, Curitiba 54: 683-690.

Mauli, M. , Nóbrega, L.H.P., Souza Filho, A.P.S., Stein, L.D.N., Cruz-Silva, C.T.A, Pacheco, F.P. 2015. Seeds germination and early development of beggartick on extracted soil solution from an area with cover crops. African Journal of Agricultural Research 10: 3123-3133.

Moraes, P. V. D., Agostinetto, D., Panozzo, L. E., Tironi, S. P., Galon, L., e Santos, L. S. 2011. Alelopatia de cover crops na superfície ou incorporadas ao solo no controle de *Digitaria* spp. Planta Daninha 29: 963-973.

Moreira, F.M.S., Siqueira, J.O. 2006. Microbiologia e Bioquímica do Solo. Editora UFLA, Lavras, Brazil. 729 p.

Nunes, J.V.D., Melo, D., Nóbrega, L.H.P., Loures, N.T.P., Fariña Sosa, D.E.F. 2014. Atividade alelopática de extratos de plantas de cobertura sobre soja, pepino e alface. Revista Caatinga 27: 122-130.

Pedrol, N., González, L., and Reigosa, M. 2006. Allelopathy and abiotic stress. Cap. 9. *In:* Reigosa, M.J., Pedrol, N., and Gonzalez, L. (Eds). Allelopathy: A Physiological Process with Ecological Implications. Springer, Netherlands. 637 p.

Pimentel G., F. 2000. Curso de Estatística Experimental. 14. ed. Degaspari, Piracicaba, Brazil. 477 p.

Rains, G.C., Olson, D.M. and Lewis, W.J. 2011. Redirecting technology to support sustainable farm management practices. Agricultural Systems 104: 1:365-370.

Rice, E.L. 1974. Allelopathy. New York: Academic Press, United States. 333 p.

Ruiz, H.A., Ferreira, G.B., Pereira, J.B.M. 2003. Estimativa da capacidade de campo de latossolos e neossolos quartzarênicos pela determinação do equivalente de umidade. Revista Brasileira de Ciência do Solo 27: 389-393.

Santos, H.P., Reis, E.M. 2003. Rotação de culturas. Cap 1. p. 13-132. In: Santos, H.P.; Reis, E. M. Rotação de Culturas em Plantio Direto. 2 ed. Passo Fundo: Embrapa Trigo, 212 p.

Seigler, D.S. 2006. Basic pathway for the origin of allelopathy compounds. Cap. 2. *In:* Reigosa, M.J., Pedrol, N., and Gonzalez, L. (Eds). Allelopathy: A Physiological Process with Ecological Implications. Springer, Netherlands. 637 p.

Silva, P.S.S. 2012. Atuação dos aleloquímicos no organismo vegetal e formas de utilização da alelopatia na agronomia. Revista Biotemas, 25: 65-74.

Souza Filho, A.P. 2006. Alelopatia e as plantas**.** Belém: EMBRAPA Amazônia Oriental. 159 p.

Weih A., U.M.E., Didon A., A.C., Rönnberg-Wästljung B., C. and Björkman, M. 2008. Integrated agricultural research and crop breeding: Allelopathic weed control in cereals and long-term productivity in perennial biomass crops. Agricultural Systems 97: 99-107.