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EFFECT OF WINTER COVER CROP BIOMASS ON SUMMER WEED EMERGENCE AND BIOMASS PRODUCTION

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Abstract: A greenhouse assay was carried out to evaluate the effect of winter cover crop residues on spontaneous plants that commonly occur on summer annual fields in Southern Brazil. Dry shoot residues of rye (*Secale cereale*), vetch (*Vicia villosa*), fodder radish (*Raphanus sativus*), and a mix of the three species, were applied over pots that had been seeded with alexandergrass (*Brachiaria plantaginea*), hairy beggarticks (*Bidens pilosa*), wild poinsettia (*Euphorbia heterophylla*), and morning glory (*Ipomoea grandifolia*) at four different depths (0, 1, 2, or 4 cm). Plant emergence and biomass production were measured. Residues of rye reduced the emergence of *B. plantaginea*, while vetch diminished *I. grandifolia* and *B. plantaginea* emergence. Fodder radish reduced emergence of *I. grandifolia*. The mix of cover crops reduced emergence of *I. grandifolia*, *B. plantaginea*, and *B. pilosa*. None of the cover crops differed from the control on *E. heterophylla* emergence. The lowest yields in spontaneous plant shoot biomass were obtained from the cover with rye + vetch + fodder radish. The lowest values of root biomass occurred under cover with rye, fodder radish or the mix. Use of vetch residues decreased emergence of *B. plantaginea* and *I. grandifolia*, but enhanced biomass accumulation by the latter.

Key words: mulch, no-till, soil cover, spontaneous plants

INTRODUCTION

There is a growing concern over weed management aimed at reducing the impact of weeds on crop yields. The increased number of work hours farmers have been dedicating to reducing the amount of weeds proves that there is a need for weed management (Blackshaw *et al.* 2008). In the past few decades, herbicides have been used almost exclusively in weed management (Valantine-Morison *et al.* 2008). But herbicides have been compromising the agroecosystem's sustainability (Mortensen *et al*. 2012).

It is possible to use technically and economically viable weed management practices and agroecosystem designs that reduce or even eliminate the need for herbicide use. Among the alternatives is the use of cover crops. Cover crops may provide such an efficient control of weeds that sometimes there is no need for the use of chemical or mechanical control (Hartwig and Ammon 2002). The use of cover crops can enable a transition from conventional chemical based systems to organic ones. The potential for environmental contamination and degradation of natural resources is thus, reduced (Altieri *et al.* 2011).

Residues from the previous crop may contain allelopathic substances (allelochemicals), capable of affecting the emergence of weeds. The allelopathic substances cause changes in density, growth, and consequently in seed production (Valantine-Morison *et al.* 2008). Winter cover crops commonly used for soil cover in no-tillage systems have different suppressive effects on weeds, depending on the weed species and the depth of the seed location of the weeds, in the soil profile. Rye (*Secale cereale*), vetch (*Vicia villosa*), and fodder radish (*Raphanus sativus*) are widely used as winter cover crops by farmers in southern Brazil. These winter cover crops can be sown either in monocultures or in mixtures. However, little is known about the mechanisms involved, or how much the use of these plants or associations, influence spontaneous plant populations.

The aim of the present study was to determine the effect of rye, vetch, fodder radish, and the mixture of rye + vetch + fodder radish shoot residues, on the plant emergence and biomass production of four of the most common and harmful weed species in Southern Brazil (*Euphorbia heterophylla*, *Ipomoea grandifolia*, *Brachiaria plan-*

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taginea and *Bidens pilosa*) sown in four different depths. These species were chosen because of their importance and impact on summer annual crops in Southern Brazil.

MATERIALS AND METHODS

The experiment was carried out in a greenhouse, in Florianopolis, in southern Brazil, (27°35′54.06″S, 48°30′55.46″W) during late spring, between November and December, with mean temperatures of 21.5 and 23.3°C, respectively. In order to simulate cover crop effects on the germination and shoot biomass of four spontaneous plant species, dried shoot biomass of rye (*S. cereale*), vetch (*V. villosa*), and fodder radish (*R. sativus*) was added to cover the pot substrates, either as monoculture or in consortium, simulating a mulch effect. Seeds of alexandergrass (*B. plantaginea*), hairy beggarticks (*B. pilosa*), wild poinsettia (*E. heterophylla*), and morning glory (*I. grandifolia*) were placed on the surface or at three different depths.

The seeds of the spontaneous plants were collected in a crop field in Campos Novos (27°23′9.90″S, 51°13′2.88″W, 940 meters above sea level, Alfisol) during the previous fall. The seeds were then pre-selected and stored in a cold chamber at 8±1°C for six months. To assess the viability of the seed population, expressed as the germination percentage, two germination tests were carried out in a growth chamber (8/16 hours day/night, 20/30°C). One hundred seeds of each species were placed in acrylic boxes (gerbox) lined with paper that had been moistened with distilled water. The average germination percentage of weed seeds in the two tests (*I. grandifolia* = 76%, *E. heterophylla* = 65%, *B. plantaginea* = 35%, and *B. pilosa* = 73%) were used to determine the number of viable seeds to be placed in each experimental unit.

Cylindrical pots (20 cm height, 10 cm diameter) were filled with 1.0 kg of washed coarse sand, previously sieved (0.1 mm) and disinfested in a 1% sodium hypochlorite solution (30 minutes). The substrate received controlled-release fertilizer, Osmocote Plus™ (The Scotts Company, USA), containing 05-18-09 NPK + 2MgO + trace elements, with an estimated release time of 3–4 months at 21°C. The fertilization corresponded to 1,000, 277 and 500 kg/ha of N, P, and K, respectively.

Each pot received the equivalent of 30 viable seeds of one weed species (*B. plantaginea*, *B. pilosa*, *E. heterophylla*, and *I. grandifolia*), placed at a depth of 0, 1, 2, or 4 cm. Air-dried shoots of the winter cover crops (rye, vetch, fodder radish, and a combination of the three species) were placed on the surface of each pot to simulate the cover observed in the field. The cover crops were collected from a field in spring, at the sowing of the summer crops, from the same location. The amount of dry biomass of winter cover-crops added to each pot was calculated according to the data of Monegat (1991): rye = 4.3 g (4.0 Mg/ha), vetch = 3.8 g (3.5 Mg/ha), fodder radish = 3.3 g (3.0 Mg/ha) rye + vetch + fodder radish = 2.1 g + 1.8 g + 1.3 g (2.2 + 1.9 + 1.4 Mg/ha, respectively). The control was composed of 5.0 g of white polyethylene straws cut into 2.5 cm long fragments, in order to simulate the physical effects of plant cover.

The number of emerged plants was recorded daily until the 11th day, when the population in each pot was lowered to two plants per pot. This was done in order to homogenize effects and avoid detrimental intraspecific competition. Weed biomass was harvested 20 days later, and shoot and root biomasses were weighed after drying at 65°C until the weight was constant.

The experimental design was a 5x4x4 factorial (five covers, four weed species, and four depths), with 10 replicates. The data were submitted to analysis of variance, comparison of means with the *t* test at 5% probability [data were transformed to Log Base and (X + 1)], and a multiple comparison test (Kruskal-Wallis, $p < 0.05$).

RESULTS AND DISCUSSION

Weed germination

There were differences among plant species in emergence (Table 1). The average number of those plants which emerged on the 11th day was less than one plant per pot for *I. grandifolia*, which was significantly affected by all covers, with the exception of the rye cover (*S. cereale)*. The other species varied between three and six plants per pot. All values were lower than those expected from the data obtained in the germination test. The cover with rye reduced the germination of *B. plantaginea* by almost 22%, compared to the control. This result confirms the results of Dhima *et al.* (2006), who observed that this cover crop caused significant reductions in the germination of three other Poacea family species: crabgrass (*Digitaria sanguinalis*), barnyardgrass (*Echinochloa crusgalli*), and *Setaria verticillata*.

Table 1. Number of emerged weeds per pot with different covers on the eleventh day after sowing

Weed	Cover	Plant number	Difference from the control
		Percentage	
Morning glory	rye	0,78	34,48
	vetch	0,35*	–39,66
	fodder radish	0,43*	–25,86
	R + V + F	0,40*	–31,03
	Control	0,58	
Wild poinsettia	rye	6,23	1,63
	vetch	5,35	–12,72
	fodder radish	5,85	–4,57
	R + V + F	5,93	–3,26
	Control	6,13	
Alexander grass	rye	3,73*	–21,97
	vetch	3,33*	–30,33
	fodder radish	4,25	–11,09
	R + V + F	3,38*	–29,29
	Control	4,78	
Hairy beggarticks	rye	3,30	–36,54
	vetch	3,48	–33,08
	fodder radish	2,93	–43,65
	R + V + F	2,78*	–46,54
	Control	5,20	

Values followed by an asterisk in the same column and within weed species differ significantly from the control according to the t test ($p \leq 0.05$)

Residues of vetch (*V. villosa*) significantly reduced the emergence of *I. grandifolia* and *B. plantaginea,* by 40 and 30%, respectively. The effect of substances extracted from legume plants on weed germination was reported by Caamal-Maldonado *et al.* (2001) and Teasdale *et al.* (1991), who found a decrease of up to 75% in the density of weeds in no-tillage systems with residues of *V. villosa* and *S. cereale*. Teasdale and Daughtry (1993) observed that fresh biomass of *V. villosa* had a suppressive effect on weeds which was even more marked than the suppressive effect of the dry biomass used in this work. Since *I. grandifolia* causes difficulties for mechanical harvesting in infested fields, an emergence reduction of almost 40% may constitute a strategy to facilitate mechanical harvest.

The cover with fodder radish reduced emergence of *I. grandifolia* by 25%, compared to the control, whereas for other weed species there were no significant effects. The dry biomass of the rye + vetch + fodder radish mix differed from the control, reducing emergence rates of *I. grandifolia*, *B. plantaginea,* and *B. pilosa* by 31, 29, and 46%, respectively. The combination of the three species of winter cover crops was responsible for the highest reductions in the emergence of *B. plantaginea* and *B. pilosa.* Wild poinsettia (*E. heterophylla)* was the only weed species that showed no significant differences in emergence when compared to the control, in all treatments. That lack of significant differences in emergence may be due to the delay in germination by part of the seeds, which shows a sigmoid pattern that probably reduced the exposition of spontaneous plant seedlings to the allelopathic compounds leached from the cover crops.

Plants of *I. grandifolia* showed no significant emergence rates, with values under 10% regardless of sowing depth or cover crop used. This was true despite a 76% germination rate in previous germination tests. The emergence rate of *E. heterophylla* stabilized between the fifth and sixth days (data not shown), regardless of the sowing depth and applied cover crop. *B. plantaginea* showed a slight increase in the number of emerging plants in the same period. It can be assumed, that this would occur later in soils with higher levels of clay and/or organic matter, in contrast to the sand substrate with its higher leaching potential. *B. pilosa* showed marked differences in germination; there was higher germination in the treatment with seeds on the surface under the inert material (the control). This species is sensitive to light limitation. *B. pilosa* tends to have higher percentages of germination when the seeds are closer to the soil surface (Reddy and Singh 1992). Furthermore, germination of the seeds of this species decrease as a soaking period increases (Reddy and Singh 1992). For these reasons, it is assumed that the germination of *B. pilosa* seeds placed on the surface (at 0 cm depth) was strongly influenced by all cover crops during the evaluation period.

Weed biomass production

The covers with rye and the consortium of rye + vetch + fodder radish, provided the lowest yields of shoots and roots of *E. heterophylla*. These yields were less than half that of the biomass produced by plants in the control treatment (Table 2). These data confirm the field studies that underlined the effect of the Poaceae species biomass used as winter cover crops to reduce the dry weight of summer weeds in annual crops fields under no-tillage systems in the region from which the seeds and plant mulch were collected (Bittencourt *et al.* 2009; Altieri *et al*. 2011). Both treatments; rye and the combination of the tree cover crops, reduced the shoots biomass production of *I. grandifolia* and *B. pilosa*. The root biomasses of *E. heterophylla* and *I. grandifolia* were lower in the treatments with rye. The values were 7 and 52% lower than the control treatment, respectively.

Table 2. Dry shoot and root biomass of weeds in pots with different winter cover crops

Weed	Cover crop	Dry biomass	
		Shoots	Roots
Morning glory	rye	0.80 b	0.60 c
	vetch	1.32 a	1.09 a
	fodder radish	1.03 ab	0.96 a
	R + V + F	0.75 b	0.74 ab
	The control	0.86 b	0.65 ab
Wild poinsettia	rye	0.22 c	0.11 c
	vetch	0.44 a	0.22 a
	fodder radish	0.34 b	0.16 b
	R + V + F	0.22 c	0.11 c
	The control	0.45 a	0.23 a
Alexander grass	rye	0.56 b	0.77 b
	vetch	0.63 ab	0.83 ab
	fodder radish	0.54 bc	0.69 b
	R + V + F	0.47 c	0.73 b
	The control	0.71 a	1.03 a
Hairy beggarticks	rye	0.38 bc	0.29 b
	vetch	0.53 a	0.46 a
	fodder radish	0.45 ab	0.39 a
	R + V + F	0.33 c	0.28 b
	The control	0.52 a	0.48 a

Means followed by same letter in each column and within weed species do not differ significantly by the t test ($p < 0.05$)

The treatment with fodder radish did not differ from rye + vetch + fodder radish regarding the effect over shoot biomass production by *I. grandifolia* and *B. plantaginea*. The cover with fodder radish was related to the lowest root biomass of *B. plantaginea*, compared to the control, but it did not differ significantly from the other cover crops.

The shoot and root biomass of weeds under vetch were greater than under the other cover crops. The greater shoot and root biomass of weeds was probably due to the higher vetch nitrogen content, that may have leached, and increased weed growth. For *I. grandifolia*, shoot biomass was significantly higher under vetch; it was also higher when compared to the control. Regarding the other weeds species, the nitrogen leached from vetch could have compensated for the suppressive effects of the cover crops.

The mixture of rye + vetch + fodder radish provided significant reductions in shoot biomass production for all weed species, as compared to the control treatment, except for *I. grandifolia*, for which there was no significant effect. None of the cover crops had any effect in reducing the biomass production of *I. grandifolia.* The cover with rye was linked to the lowest values of total biomass production by *E. heterophylla* seeded at 1, 2, and 4 cm depths. Fodder radish and the mixture did not differ from rye at 2 and 4 cm depths. At depths of 2 and 4 cm, the biomass production of *B. plantaginea* was reduced by *S. cereale*, which also occurred when the seeds of this species were placed at 1 and 2 cm under the mixture of the three cover crops. The cover crop mix reduced the biomass production of *B. pilosa* by 46%, but all covers were effective in reducing the biomass of this spontaneous specie when compared to the control. Such results show that this weed can be potentially controlled by the use of cover crops.

Summarizing of emergence and biomass production

Table 3 summarized the differences in emergence rates and biomass production between treatments and the control. This was done to establish the types of ecological interactions occurring between the winter cover crops and summer weeds.

Table 3. Effects (positive, negative, or null) of the three cover crops or their combination, on the emergence and biomass accumulation of the four spontaneous plant species

Weed species	Effect on	Rye (R)	Vetch (V)	Fodder radish (F)	R + V + F
Morning glory	emergence	0	–	–	0
	biomass	0	+	–	0
Wild poinsettia	emergence	0	0	0	0
	biomass	–	0	–	–
Alexander grass	emergence	–	–	0	–
	biomass	–	0	–	–
Hairy beggarticks	emergence	0	0	0	–
	biomass	–	0	0	–

Although the emergence rate of *I. grandifolia* was low, even a few adult plants can cause considerable damage to summer crops due to the growth habits of *I. grandifolia*. Harvesting is made difficult due to these growth habits. For this species, only the treatment with fodder radish was effective in reducing the emergence and biomass. Use of vetch residues reduced the emergence of *I. grandifolia* but increased its biomass.

When comparing the emergence values, the use of the cover crops did not reduce the emergence of *E. heterophylla*. Although the cover crops did not affect the germination, they reduced the initial biomass production of *E. heterophylla* with the exception of the treatment with vetch. This potential for reduction in the biomass production of spontaneous plants can be useful. This is because the crop suffers less from the negative effects due to competition with the weeds for resources, such as light, water, and nutrients.

Only fodder radish did not reduce the emergence rate of *B. plantaginea*, whilst the biomass of this species was reduced by all treatments, except for vetch. Emergence of *B. pilosa* was only reduced when the mixture of all the cover crops was used, and when only rye and the mixture of the three cover crops reduced its biomass.

Regarding the cover crops, rye was not effective against *I. grandifolia*, but the rye cover crop reduced the biomass of all other weed species, which is consistent with the results obtained in field conditions (Bittencourt *et al.* 2009; Kieling *et al*. 2009; Bonjorno *et al*. 2010; Altieri *et al*. 2011). Fodder radish negatively influenced the germination of *I. grandifolia* and also reduced the biomass of *E. heterophylla* and *B. plantaginea*. Vetch was able to reduce the emergence of *I. grandifolia* and *B. plantaginea*, but vetch did not affect weed biomass, except for *I. grandifolia*, which had its growth enhanced by vetch residues. In summary, effects on plant emergence and growth can be complementary or even antagonistic.

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