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Effects of sericea lespedeza residues on cool-season grasses

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Abstract

Incorporation of crop residues into the soil prior to planting has been shown to reduce the growth of subsequent crops. Information is limited on the allelopathic effect of sericea lespedeza [*Lespedeza cuneata* (Dum. Cours) G. Don.] residues on multiple cropping and rotational systems. Experiments were conducted to determine: (1) if sericea lespedeza residues affected seed germination and plant growth of rye (*Secale cereale* L.), ryegrass (*Lolium multiflorum* Lam.), and tall fescue (*Festuca arundinacea* Schreb.); (2) if cultivars of these species varied in response to phytotoxins from sericea lespedeza residues; and (3) if N fertilization nullified the effects of residues. Germination experiments were conducted by using water extracts from low- or high-tannin sericea lespedeza residues, distilled water (control), and topsoil and subsoil obtained from areas in which low- or high-tannin sericea lespedeza plants had grown for 4 years. Greenhouse experiments showed that germination, emergence, seedling growth, above-ground biomass, and N concentration of rye and tall fescue were reduced by sericea lespedeza residues. Although ryegrass germination was not affected by the residues, biomass and N concentration were reduced. Rye and tall fescue germination were not affected by soils where sericea lespedeza previously had grown, but ryegrass germination and seedling growth of all 3 species were reduced. Immobilized N was the main factor limiting plant growth. Fertilizer-N more than compensated for the negative effects of the residues on all species. Establishment of rye and tall fescue in a sericea lespedeza field is likely to require higher seeding rates than normal to compensate for reduced germination, whereas ryegrass would not be affected. Fertilizer-N may be needed to enhance growth of grasses that otherwise would be curtailed by sericea lespedeza residues.

Key Words: allelopathy, legumes, plant litter, *Lespedeza cuneata*, rye, *Secale cereale*, ryegrass, *Lolium multiflorum*, tall fescue, *Festuca arundinacea*

Incorporation of crop residues into the soil has been shown to reduce growth of subsequent crops (Miller 1983, Hicks et al. 1989). This effect was associated with the release of phytotoxic substances from some crop residues (Rice 1984, Barnes et al. 1987). Guenzi and McCalla (1962) found that seed germination and seedling growth of corn (*Zea mays* L.) and sorghum [*Sorghum bicolor* (L.) Moench] were affected by water residue extracts of other crop species. Rye residues inhibited seed germination and growth of several crops and weeds (Barnes and Putnam 1986). Kalburtzi et al. (1989) reported allelopathy of wheat [*Triticum aestivum* (L.) Em. Tell] and favabean (*Vicia faba* L.) water extracts from their residues on seed germination and seedling growth.

Sericea lespedeza [*Lespedeza cuneata* (Dum. Cours) G. Don.] is a long-lived perennial used for forage production and soil conservation. Because sericea lespedeza is dormant during winter, it is recommended to overseed it with cool-season grasses to extend the productive season (Hoveland et al. 1990).

Information on allelopathic effect of sericea lespedeza residues in multiple cropping and rotational systems is limited. Langdale

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and Giddens (1967) found that sericea lespedeza stem residues incorporated into the soil depressed corn growth. Logan et al. (1969) reported autoallelopathy in seed germination and seedling growth from a sericea lespedeza seedcoat inhibitor. Cope (1982), however, detected no allelopathy of sericea lespedeza seed leachates to germination and seedling growth of 7 forage species, or to sericea lespedeza itself. Kalburtji and Mosjidis (1992) reported that sericea lespedeza residues had a minor negative effect on aboveground biomass of bermudagrass [*Cynodon dactylon* (L.) Pers.] and bahiagrass (*Paspalum notatum* Flugge) in contrast to the positive effect of N fertilization.

The objectives of this study were to determine if sericea lespedeza residues affected seed germination and seedling growth of rye, ryegrass, and tall fescue; if variability existed in the degree of tolerance among cultivars of rye, ryegrass, and tall fescue to phytotoxic compounds present in sericea lespedeza residues; and if an interaction existed between soil incorporation of sericea lespedeza residues and nitrogen (N) fertilization that influences rye, ryegrass, and tall fescue emergence and establishment.

Materials and Methods

The effects of sericea lespedeza plant residues on seed germination, seedling development, and growth of rye, ryegrass, and tall fescue were examined in a series of laboratory and greenhouse experiments. Included were 4 cultivars each of rye ('Bonel', 'Forager', 'Winter Grazer 70', and 'Gurley's Grazer 2,000') and ryegrass ('Urbana', 'Penploid', 'Gulf', and 'Marshall') and 3 tall fescues ('AU Triumph', 'KY-31' 45% endophyte infected, and KY-31 endophyte-free). In December of 1989, sericea lespedeza residues and soil samples were obtained from nurseries of high- or low-tannin genotypes that were grown for 4 years in Tallassee, Ala. High-tannin genotypes have between 270 and 304 g kg^{-1} of tannin whereas low-tannin genotypes have between 139 and 228 g kg^{-1} (Petersen et al. 1991). The nurseries were located on soil classified as Bassfield loamy fine sand (coarse-loamy, siliceous, thermic, Typic Hapludults).

Seed Germination

Two experiments were conducted on each of the 3 grass species. In the sericea lespedeza residue extract experiment, 20 seeds of each of the 4 cultivars of rye and ryegrass and of the 3 tall fescue cultivars were germinated in 3 treatments: 0, low-, and high-tannin residue extracts. The 0-tannin (control) treatment was distilled water. Low- and high-tannin treatments were water extracts from low- or high tannin sericea lespedeza residues. In the soil extract experiment, 20 seeds of the same 11 cultivars were germinated in distilled water (control) and water extracts from topsoil (0 to 10-cm depth) and subsoil (10 to 30-cm depth) obtained from soil in which low- or high-tannin sericea lespedeza plants had grown for 4 years.

Residue and soil extracts were obtained by grinding 50 g of residue or mixing the same amount of soil with 500 ml of distilled water in a blender for 10 min. The mixture was agitated for 2 hours, and filtered through Whatman No. 1 filter paper. Electrolytic conductivity and pH were measured in each extract.

Seeds were germinated on Whatman No. 42 filter paper moistened with 5 ml extract or distilled water in petri dishes placed in an incubator in the dark at 22/15° C for 16/8 hours. Percentage seed germination and radicle and coleoptile lengths were recorded after 7 days incubation. Seeds were considered germinated if the radicle had protruded and through the seed coat.

Data were analyzed by species as a factorial experiment in a split plot design with 5 replications where main plots were grass cultivars and subplots were treatments. In the residue extract experiment, treatments were tannin levels and, in the soil extract, soil depths and tannin levels.

Seedling Emergence and Growth

Ten grass seeds of each cultivar were planted in 1,890-cm^3 pots filled with potting soil (13% peatmoss, 57% fine sandy loam soil, and 30% sand, pH 5.5) in the greenhouse. Prior to planting sericea lespedeza residues (11% stems, 85% leaves, and 4% seeds) were thoroughly mixed with the soil before placing in the pots. The potting soil contained 1.7% organic matter, 1.4 g total N kg^{-1}, and 63 mg P kg^{-1}. Exchangeable cations were 3.4, 1.1, and 0.2 cmol kg^{-1} for Ca^{2+}, Mg^{2+}, and K^{1+}, respectively. Mean day and night temperatures during the time that the experiments were conducted were 28 and 15.5° C, respectively.

Treatments were a factorial combination of 3 rates of sericea lespedeza residues (0, 6, and 12 g pot^{-1}), 2 rates of N (0 and 30 mg kg^{-1} of soil) applied 4 times during the growth of the grasses, and 2 types of sericea lespedeza residues (low- and high-tannin content) applied to 3 or 4 cultivars depending on the species. The rates of residue are representative of the amounts found in fields with no sericea lespedeza, with sericea lespedeza grown for hay production (3,800 kg ha^{-1}), and with sericea lespedeza grown for soil conservation or biomass production (7,600 kg^{-1}) for 4 years and cut once at the end of each summer. These rates were determined by sampling sericea lespedeza fields near Tallassee, Ala. The N source was 135 mg of ammonium nitrate (33% N) in 50 ml of water applied to each pot at the beginning of the experiment and every 15 days thereafter.

Seedling emergence was recorded 7 days after sowing. Fifteen days after sowing, the plants were thinned to 5 plants pot^{-1}. Plants were harvested 55 days after sown, dried at 65° C for 72 hours, and weighed. This material was ground to pass an 18-mesh sieve and analyzed for total N on a Leco N analyzer.

Within each species, data were analyzed as a factorial experiment in a split plot design where cultivars were the main plots and treatments (sericea lespedeza residue rates, N rates, and type of sericea lespedeza residue) were the subplots. There were 4 replications (pots) of each treatment. Comparison between treatment means were done according to the least significant test and single degree of freedom contrast (Gomez and Gomez 1984).

Results and Discussion

Seed Germination

Sericea lespedeza residue extracts did not affect either germina-

Table 1. Effects of low- and high-tannin sericea lespedeza residue extracts on rye, ryegrass, and tall fescue seed germination and seedling length, averaged across cultivars.

Treatment	Seed germination			Radicle length			Coleoptile length		
	Rye	Ryegrass	Tall fescue	Rye	Ryegrass	Tall fescue	Rye	Ryegrass	Tall fescue
	(%)			(cm)					
Control	85	96	79	6.1	5.4	3.2	3.2	3.5	2.4
Low tannin	82	94	77	5.5	5.5	1.6	2.8	3.6	2.3
High tannin	79	94	75	5.2	5.5	1.6	2.7	3.6	1.9
LSD (0.05)	3	ns	ns	0.2	ns	0.2	0.2	ns	0.3

Table 2. Means of seed germination and seedling growth after 7 days of rye, ryegrass, and tall fescue as affected by soil extracts, averaged across cultivars.

	Seed germination			Seedling growth					
				Radicle length			Coleoptile length		
Treatment	Rye	Ryegrass	Tall fescue	Rye	Ryegrass	Tall fescue	Rye	Ryegrass	Tall fescue
	(%)			(cm)					
Control	ns	99	ns	7.6	7.2	2.7	5.7	4.3	1.9
All extracts	ns	96	ns	6.5	5.7	2.4	4.4	3.4	1.7
Soil depth									
0–10 cm	—[1]	97	—	6.1	—	ns	3.9	—	ns
10–30 cm	—	95	—	6.8	—	ns	4.9	—	ns
Tannin level									
Low	—	96	—	6.6	—	2.5	4.6	—	1.7
High	—	95	—	6.3	—	2.4	3.9	—	1.6

All comparisons within soil depths and tannin levels are significant (P = 0.05).
[1]No data.

tion or seedling growth of ryegrass when compared to the control (Table 1). They also had no effect on tall fescue seed germination, but reduced germination of rye and seedling growth of both rye and tall fescue. Similar effects have been observed on bermudagrass and bahiagrass by Kalburtji and Mosjidis (1992).

Extracts from high-tannin sericea lespedeza residues decreased rye seed germination by 7% compared to the control, whereas extracts from low-tannin residues had no effect (Table 1). Rye radicle length was reduced 10 and 15% by extracts from low- and high-tannin, respectively. There was a significant ($P<0.01$) cultivar-extract interaction for radicle length in rye, but this accounted for only a small portion (3.8%) of the variability. Low-tannin residue extract reduced rye coleoptile length, averaged over cultivars, by 13%, whereas high-tannin extract diminished rye coleoptile length by 16%.

Tall fescue was more sensitive to residue extracts than rye (Table 1). Its seedlings had a 50% reduction in radicle length in the presence of high- or low-tannin residue extracts, whereas coleoptile length was reduced 21% but only in the presence of high-tannin residue extract. These results can be explained by the reported reduction of cell elongation or division due to phytotoxins released by plant material into the environment (Rice 1984).

Soil extracts had no effect on rye and tall fescue seed germination, whereas ryegrass germination was reduced slightly (Table 2). Rye and tall fescue had radicle and coleoptile lengths reduced by the soil extracts. Topsoil extracts reduced rye radicle and coleoptile length more than subsoil extracts.

Extracts from soil in which high-tannin plants previously had grown reduced ryegrass germination as well as rye and tall fescue radicle and coleoptile length more than from soils in which low-tannin plants had grown (Table 2).

There was a significant ($P<0.01$) soil depth by tannin level interaction on ryegrass seedling growth. Extracts from subsoil samples where high-tannin plants had grown reduced radicle and coleoptile length more than those from where low-tannin plants had grown (Table 3). Topsoil extracts inhibited ryegrass radicle and coleoptile length more than subsoil, regardless of the tannin level.

Analyses of soil extracts indicate that soils were sericea lespedeza had grown for 4 years contained inhibitors of plant growth regardless of the soil depth or the tannin level in the residues. Overall, topsoil and high-tannin residues had a more pronounced effect than subsoil and low-tannin residues. This suggested that sericea lespedeza plants and their residues released phytotoxic compounds to the surrounding environment. Guenzi and McCalla (1966) reported that compounds produced during crop residue and soil organic matter decomposition reduced the yield of several crop species. Also, living plants can release substances that accumulate in the soil in amounts that are harmful to other species (Kil and Lee 1987, Dornbos et al. 1990). This could explain why ryegrass was affected by soil extracts and not by the residue extracts.

Table 3. Effects of sericea lespedeza soil extracts on early seedling growth of ryegrass, averaged across cultivars.

Treatment	Radicle length	Coleoptile length
	(cm)	
Subsoil		
Low	6.8	4.0
High	6.0	3.6
Topsoil		
Low	ns	ns
High	ns	ns
Low-tannins		
0–10 cm	5.1	3.0
10–30 cm	6.8	4.0
High-tannins		
0–10 cm	5.1	3.0
10–30 cm	6.0	3.6

All comparisons within soil depths and tannin levels are significant (P = 0.05) unless otherwise indicated.

Although the interaction between tall fescue cultivars and treatments was not significant in the experiments conducted, cultivar KY-31 endophyte infected had better germination (91 vs. 51%) than KY-31 endophyte free. The endophyte-infected cultivar had radicle (2.7 vs. 1.6 cm) and coleoptile (2.3 vs. 1.4 cm) length longer than endophyte free KY-31.

The pH of residues and soil extracts ranged from 5.2 to 5.6 and from 5.2 to 6.2, respectively. Electrolytic conductivities of the residue and soil extracts ranged from 0.24 to 0.42 and 0.23 to 0.31 dS m^{-1}, respectively. No relationship was observed between pH or electrolytic conductivity and seed germination or growth response. These findings agree with other reports (Yakle and Cruse 1984, Martin et al. 1990).

Seedling Emergence and Growth

Cultivar and amount of residue accounted for most of the variability in emergence of rye and tall fescue. Sericea lespedeza residues incorporated into the soil reduced rye and tall fescue emergence, but had no effect on ryegrass. When compared to the control (0 g pot^{-1}), rye and tall fescue emergence were reduced 5 and 6%, respectively, by 6 g of residue per pot and 8 and 12%, respectivly, by 12 g of residue per pot (Table 4). Differences in emergence between the 2 levels of residues were not significant. These results are consistent with our germination experiments where rye germination and radicle and coleoptile length were reduced by extracts from sericea lespedeza residues. Similarly, radicle and coleoptile length of tall fescue were reduced by the residues. Nitrogen rate and

Table 4. Effects of sericea residues with low or high tannin content and N fertilization on rye, ryegrass, and tall fescue seedling emergence and biomass, averaged across cultivars.

	Emergence			Biomass		
Treatment	Rye	Rye-grass	Tall fescue	Rye	Rye-grass	Tall fescue
	(%)			(g pot^{-1})		
Nitrogen rate						
0 mg kg^{-1}	93	99	89	0.71	0.83	0.95
30 mg kg^{-1}	94	99	92	2.72	1.95	2.35
LSD (0.05)	ns	ns	ns	0.12	0.09	0.13
Tannin level						
Low	93	100	92	1.77	1.40	1.65
High	94	99	89	1.66	1.38	1.64
LSD (0.05)	ns	ns	ns	ns	ns	ns
Residue rate						
0 g pot^{-1}	98	100	96	1.99	1.56	1.93
6 g pot^{-1}	93	99	90	1.72	1.39	1.51
12 g pot^{-1}	90	99	85	1.44	1.22	1.49
LSD (0.05)	4	ns	5	0.14	0.11	0.15

tannin level had no effect on emergence of any species.

Most interactions among cultivars, residue rates, tannin levels, and N rates were not significant for emergence. The rye cultivar-residue rate interaction was significant ($P<0.01$) for emergence. Bonel and Winter Grazer 70 were the least affected cultivars, while Forager and Gurley's Grazer 2000 were the most affected (Fig. 1).

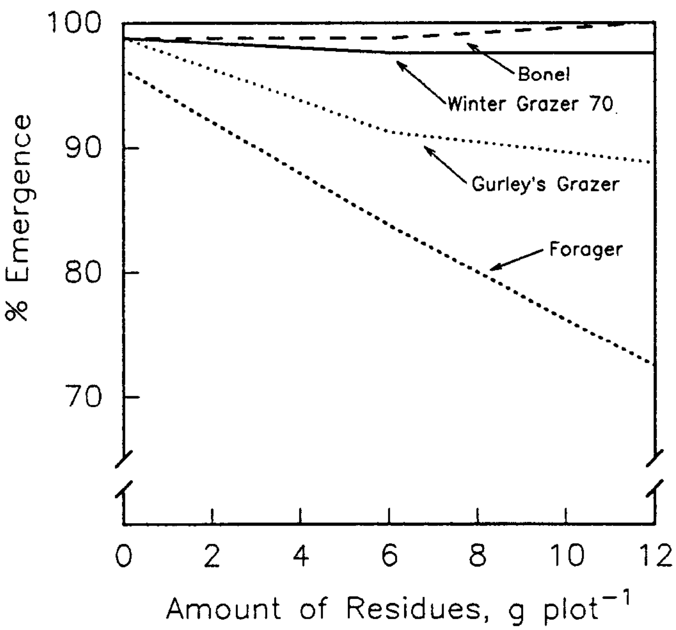

Fig. 1. Effect of sericea lespedeza residues on seedling emergence of 4 rye cultivars.

For all species studied, main effects of cultivars, N application, and amount of residue were significant for above-ground biomass. Nitrogen application accounted for most of the variability in dry weight. Nitrogen application increased biomass dry weight of rye, ryegrass, and tall fescue 74%, 57%, and 60%, respectively. Tannin level had no effect on growth (Table 4).

Above-ground biomass production of all species decreased in the presence of sericea lespedeza residues. Rye biomass dry weight was reduced 14% by the low and 28% by the high amount of residue, when compared to the control, whereas reductions in ryegrass biomass dry weight were 11% and 22% and in tall fescue 22% and 23%, respectively (Table 4). Ryegrass was the species least affected by sericea lespedeza residues. With the exception of tall fescue, we found that the greater the amount of residue the lower the above-ground plant dry weight. Sericea lespedeza residues had similar effects on bermudagrass and bahiagrass (Kalburtji and Mosjidis 1992).

Regardless of the species, most interactions among cultivars, residue rates, tannin levels, and N rates were not significant for above-ground biomass. The only significant interactions were N-residue rate for rye biomass and cultivar-N for dry weight of the species studied; however, these interactions accounted for only a small portion (0.8 to 1.7%) of the total variability.

As in the germination experiments, endophyte-infected tall fescue out-performed endophyte-free in greenhouse experiments. It had greater emergence (95 vs. 80%) and biomass (1.6 vs 1.3 g pot^{-1}) than endophyte-free tall fescue.

For all species studied, there were significant main effects of cultivars, N application, and amount of residue on shoot N concentration. Nitrogen application increased shoot N concentration 104%, 143%, and 43% in rye, ryegrass, and tall fescue, respectively (Table 5), and accounted for most of the variability observed.

Table 5. Effects of sericea lespedeza residues with low or high tannin content and N fertilization on content of N in shoots of rye, ryegrass, and tall fescue, averaged across cultivars.

	Shoot-N		
Treatment	Rye	Ryegrass	Tall fescue
	(g kg^{-1})		
Nitrogen rate			
0 mg kg^{-1}	21.7	21.4	17.7
30 mg kg^{-1}	44.2	51.9	25.3
LSD (0.05)	0.9	1.1	0.9
Tannin level			
Low	32.8	36.9	21.4
High	33.1	36.5	21.6
LSD (0.05)	ns	ns	ns
Residue rate			
0 g pot^{-1}	34.7	39.5	23.9
6 g pot^{-1}	32.7	36.1	21.2
12 g pot^{-1}	31.5	34.4	19.4
LSD (0.05)	1.2	1.3	1.1

Shoot nitrogen concentration in all species was reduced as the amount of sericea lespedeza residue incorporated in the soil increased (Table 5). When compared to the control the reduction in N concentration caused by the low level of residue applied to the pots was 6, 9, and 11% for rye, ryegrass, and tall fescue, respectively. The high residue rate reduced N concentration 9, 13, and 19% for rye, ryegrass, and tall fescue, respectively. Tannin level had no effect on shoot N concentration. Although the interactions N-residue rate in rye and ryegrass, cultivar-residue rate in tall fesuce, and cultivar- N-tannin level in ryegrass were significant, they accounted for only a small portion (0.3 to 2.6%) of the variability in N content.

Results reported in this paper agree with those of Kalburtji and Mosjidis (1992) in warm-season forage grasses and Langdale and Giddens (1967) who observed that incorporation of different rates of sericea lespedeza stem residue into the soil reduced corn growth. Langdale and Giddens (1967) related this response to the release of phenolic compounds from sericea lespedeza residue.

In conclusion, reductions in seed germination of rye and seedling growth of rye and tall fescue by extracts from sericea lespedeza residues; reductions in ryegrass germination and in seedling growth of the 3 grass species by extracts from soils where sericea lespedeza had grown for 4 years; and reductions in emergence, above-ground biomass, and N concentration of rye and tall fescue by incorporation of sericea lespedeza residues in the soil indicate that establishment of rye and tall fescue in a sericea lespedeza field is likely to require higher seeding rates than normal to compensate for reduced emergence. Although ryegrass emergence was not reduced by the soil incorporation of the residues, its above-ground biomass and N concentration were. Immobilization of N appeared to be the main factor limiting plant growth and N fertilization more than compensated for the negative effects of the residues on all species. Hence, N fertilization is needed to enhance growth of the 3 grasses that otherwise would be curtailed by sericea lespedeza residues.

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