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Natural Herbicide Potential of Alfalfa Residue on Selected Weed Species

Ill-Min Chung and Darrell A. Miller*

ABSTRACT

Alfalfa (*Medicago sativa* L.) contains water-soluble substances that are toxic to itself (autotoxicity) and to other species (allelopathy). Experiments were conducted to determine the potential of using alfalfa residue as a natural herbicide for inhibition of weed seed germination, seedling growth, and development. Various weed species were germinated in aqueous extracts from dried alfalfa using cold (5°C), warm (24°C), and hot (80°C) treatments. Results indicated that inhibition of weed seed germination was dependent on the aqueous extraction method, residue application rate (w/v or w/w), and weed species. The greatest inhibition of germination was 44%, when 60% (w/v) warm aqueous extract was applied to lambsquarters (*Chenopodium album* L.). Seedling growth was also inhibited by residue application at various rates. Root length was more inhibited than increase in shoot length. In terms of total seedling length, giant foxtail (*Setaria faberii* Herrm.) was the most resistant species and lambsquarters was the most susceptible among the weed species studied to alfalfa aqueous extracts. Weed seed germination percentage decreased as incubation time increased from 8, 16, 24, and 48 h. An alfalfa aqueous extract incubated for 48 h caused the greatest inhibition of velvetleaf (*Abutilon theophrasti* Medic.) seed germination (25%). When alfalfa residue was incorporated with silica sand, the growth and development of lambsquarters, pigweed (*Amaranthus retroflexus* L.), velvetleaf, and crabgrass [*Digitaria sanguinalis* (L.) Scop.], as measured by plant height, leaf area, and total, shoot, leaf, and root dry weight, were significantly inhibited as the rate increased from 0.0 to 2.0 g kg^{-1}. Dried alfalfa residue significantly stimulated plant height, leaf area, and total dry weight including shoot, leaf, and root of giant foxtail and cheatgrass (*Bromus secalinus* L.). Results suggest that alfalfa residue has a contrasting effect on weed growth and development due to water-soluble allelochemicals present in the residue.

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ALLELOPATHY is defined as the direct or indirect harmful or beneficial effects of one plant on another through the production of chemical compounds that escape into the environment (Rice, 1984). Many of the phytotoxic substances suspected of causing germination and growth inhibition have been identified from plant tissues and soils. These substances are termed *allelochemics* (Whittaker and Feeny, 1971) or, more commonly, *allelochemicals*. Allelochemicals usually are called secondary plant products or waste products of the main metabolic pathways in plants (Swain, 1977). These may be water-soluble substances that are released into the environment through leaching, root exudation, volatilization, and decomposition of plant residues. In addition, Gressel and Holm (1964), Elmore (1980), and Friedman and Waller (1983) reported that allelochemicals may be released from seeds in the soil.

Most research on allelopathy has focused on the effect of interactions among weed species (Wilson and Rice, 1968; Rasmussen and Rice, 1971; Newman and Rovira, 1975), weeds and crops (Tukey, 1969; Bell and Koeppe, 1972; Tames et al., 1973; Putnam and Duke, 1974; Rice, 1979, 1984; Colton and Einhellig, 1980), and crop species (Benedict, 1941; Guenzi and McCalla, 1962; Klein and Miller, 1980; Jensen et al., 1981; Miller, 1983; Ells and McSay, 1984; Hall and Henderlong, 1989; Hegde and Miller, 1992). With increased conservation tillage practices, the possibility of utilizing allelopathic effects to control weeds has received considerable attention, as natural herbicide compounds from various plants exhibit allelopathic selectivity against certain weed species (Brooks, 1951; Overland, 1966; Bell and Koeppe, 1972).

A living cover of spring-planted winter rye (*Secale cereale* L.) reduced early season biomass of lambsquarters (*Chenopodium album* L.) by 98%, crabgrass [*Digitaria*

sanguinalis (L.) Scop.] by 42%, ragweed (*Ambrosia artemisiifolia* L.) by 90% and total weed biomass by 94% (Borner, 1950). Overland (1966) researched the efficacy of barley (*Hordeum vulgare* L.) as a smother crop for weed suppression and suggested that allelopathy is involved in this interference with weed growth.

White et al. (1989) reported inhibition of several weeds by field residue and leachates of crimson clover (*Trifolium incarnatum* L.) and hairy vetch [*Vicia villosa* (L.) Roth]. Hairy vetch residues inhibited pigweed (*Amaranthus retroflexus* L.), green foxtail [*Setaria viridis* (L.) Beauv.] and velvetleaf (*Abutilon theophrasti* Medic.) growth (Teasdale, 1988). Seed excretions of hairy vetch also were particularly inhibitory to weed seed germination and seedling growth of numerous weed species (Lazauskas and Balinevichiute, 1972).

Weed control resulting from the allelopathic activity of alfalfa (*Medicago sativa* L.) would be particularly important in no-till alfalfa establishment. However, little information is available on the allelopathic effect of alfalfa on weed species. Nielsen et al. (1960) studied the effects of water extracts of alfalfa, timothy (*Phleum pratense* L.), corn (*Zea mays* L.), oat (*Avena sativa* L.), and potato (*Solanum tuberosum* L.) on alfalfa, timothy, oat, soybean [*Glycine max* (L.) Merr.], chickling-pea (*Lathyrus sativus* L.), and corn. They found that alfalfa hay extracts caused the greatest delay in seed germination and seedling growth of all test species.

Alfalfa roots contain water-soluble substances that are toxic to several grasses (Lawrence and Kilcher, 1962). Guenzi et al. (1964) found that extracts of alfalfa containing saponins as water-soluble phytotoxic substances inhibited the shoot and root length of corn seedlings. Marchaim et al. (1975) reported that aqueous solutions of alfalfa root saponins reduced the germination of cotton seeds. Miller (1983) demonstrated that alfalfa contains water-soluble substances that are toxic to itself (autotoxicity) as well as to other species (allelopathy). Tsuzuki and Kawagoe (1984) reported that alfalfa root exudates inhibited the dry weight of barley, alfalfa, and radish (*Raphanus sativus* L.) seedlings.

Some researchers have evaluated the allelopathic potential of alfalfa as a natural herbicide (Abdul-Rahman and Habib, 1989; Waller, 1989; Dornbos et al., 1990; Wyman-Sympson et al., 1991). Decomposed alfalfa roots and their associated soil reduced bladygrass [*Imperata cylindrica* (L.) Beauv.] seed germination and seedling growth (Abdul-Rahman and Habib, 1989). Pure alfalfa root saponins inhibited the growth and development of cheatgrass (*Bromus secalinus* L.), barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], pigweed, dandelion (*Taraxacum officinale* L.), and coffeeweed [*Daubentonia punicea* (Cav.) DC.] (Waller, 1989). Miller et al. (1988) have implicated medicarpin, a phenol phytoalexin, in germination and growth inhibition.

This experiment was designed to determine whether allelopathy characteristics of alfalfa affects the growth and development of certain weeds. Our objectives were to (i) evaluate the effect of the phytotoxic substances released from alfalfa residue on the growth and development of selected weed species that compete with alfalfa; (ii) determine the effect of extraction at different temperatures on the extracts toxicity to weed development; and (iii) evaluate the effect of incubation time of alfalfa aqueous extracts on germination of various weed seeds.

MATERIALS AND METHODS

General Procedure

Vegetative alfalfa plants (cv. Vernal) with a minimum of 30 cm in height were harvested in August 1991 at the Agronomy and Plant Pathology South Farm at the University of Illinois and air-dried at 24°C in the forage laboratory. Dried samples were ground using a Wiley mill and a 40-mesh screen and then stored at 5°C until needed.

Residue Extract and Bioassay Test

Dry ground alfalfa (15, 30, 45, or 60 g) was extracted in 250-mL flasks by three different methods: (i) warm-temperature extract; shaking alfalfa with 100 mL of double-distilled water for 24 h at 24°C in the light; (ii) hot-temperature extract; mixing alfalfa with 100 mL of double-distilled water and allowing to stand in an 80°C water bath for 2 h; (iii) cold-temperature extract: mixing alfalfa with 100 mL of double-distilled water and placing in a refrigerator for 24 h at 5°C. All three extracts were filtered through filter paper (Whatman no. 42) and then again through a Nalgene filterware unit (0.2 mm), to prevent any plant material contamination.

Lambsquarters, pigweed, velvetleaf, giant foxtail, cheatgrass, and crabgrass seeds were used in a bioassay test after trash was removed from the seeds by floating them in distilled water. All weed seeds were surface-sterilized in a 1:10 (v/v) dilution of commercial hypochlorite bleach for 10 min and rinsed several times with distilled water. They were then allowed to imbibe on moistened paper towels for 2 h. Filter paper (Whatman no. 4) containing 50 seeds of each weed species was placed in each sterilized 9-cm-diam. petri dish before 10 mL of each residue extract was added. Treatments consisted of 0-, 15-, 30-, 45-, or 60-g residue aqueous extracts from the three different extraction methods. Petri dishes were sealed and placed in a lighted room at 24°C for 96 h. A double-distilled water treatment was used as the control. Treatments were arranged in a completely randomized design with four replications. After 96 h, percent germination was determined. If the root radicle protruded totally from the seed coat as observed with the naked eye, the seed was counted as a germinated seed.

Seedling Growth Bioassay

Fifty seeds of each weed species were germinated in petri dishes in room temperature aqueous extracts as described above. Petri dishes of the five residue aqueous extracts (0, 15, 30, 45, or 60 g residue) and six weed species in four replications were arranged in a completely randomized design. At the end of 144 h, seedling root and shoot length were measured.

Incubation Time Treatment

Dried alfalfa (30 g) was added to double-distilled water (100 mL) and placed in a lighted room at 24°C for 0, 8, 16, 24, and 48 h. Aqueous extracts were prepared in a similar manner as described above. A double-distilled water treatment was used as the control. Treatments were arranged in a completely randomized design with five replications. Fifty seeds of each weed species were germinated in petri dishes at room temperature. After 96 h, percent germination was determined. If the root

radicle protruded totally from the seed coat as observed with the naked eye, the weed seed was counted as a germinated seed.

Greenhouse Experiment

Six weed species (lambsquarters, pigweed, velvetleaf, giant foxtail, cheatgrass, and crabgrass) were grown from seed in pots (10 cm diam.) containing 500 g of silica sand in the greenhouse. To prevent water-soluble phytotoxic compounds from leaching, a brown plastic saucer was placed under each pot. A sponge plug was placed in the bottom of each pot to prevent loss of silica sand through the hole in the bottom. One needle-size tube was placed near the middle of each pot for air exchange. Ground residue was incorporated with silica sand at 0.0, 0.5, 1.0, 1.5, and 2.0 g kg^{-1}. A control with no residue was compared with the other treatments. Five treatments, including the no-residue control, were established for each species in a completely randomized design with four replications. Fifty weed seeds per pot were planted uniformly 1 cm deep. After emergence, seedlings were thinned twice until 12 plants remained in each pot. Hoagland solution I (Hoagland and Arnon, 1950) was provided to each pot every 2 d. At 35 d after planting, 12 plants from each pot were harvested. The highest extended leaf was recorded as the plant height (cm). The leaf area (cm^2 $plant^{-1}$) and the dry weight (oven-dried at 85°C for 6 h) of leaves, shoots, and roots were determined. The leaf area (LA) was measured by an automatic area meter (Type AAM5, Tokyo Hayashi Denco, Tokyo, Japan). Roots of each species were rinsed with water to remove silica sand debris and then oven-dried at 85°C.

Statistical Analysis

Aqueous germination and seedling growth experiments were repeated three times; the greenhouse alfalfa residue and incubation experiments were repeated twice. Since there were no significant interactions, the data were analyzed as a combined experiment. The pooled mean values for the treatment were separated using least significant difference (LSD) at the 0.05 probability level (SAS Inst., 1985). Linear, quadratic, and cubic regression analyses were developed for total seedling length related to aqueous extract concentrations.

RESULTS AND DISCUSSION

Residue Extract and Bioassay Tests

The extraction temperature of dried alfalfa residue affected the toxicity of the extracts (Table 1). Germination percentages were significantly reduced by all three different temperature water extraction methods. A heated water extract affected the toxicity of alfalfa extract on weed germination when compared with the control. In most cases, warm-temperature extracts (24°C) had the greatest inhibition of all weed seed germination. In all cases, the warm-extract treatment inhibited germination more than the hot treatment, except for giant foxtail at the 30% concentration. In most cases, the cold- and hot-extract treatments did not differ significantly. The germination inhibition responses differed among extract method, residue level, and weed species. The degree of extract phytotoxicity was dependent on residue concentration and weed species. Germination of lambsquarters, velvetleaf, cheatgrass, and pigweed seed was more inhibited than that of other weed species.

Earlier investigators found that autoclaving or boiling increased toxicity (Guenzi and McCalla, 1962; Ohman and Kommendahl, 1964; Jensen et al., 1984), while others found that heated extracts decreased toxicity (Siegel, 1950; Jensen et al., 1984), and still others found that heated extracts had no effect on the toxic activity of plant extracts (LeTourneau et al., 1956; Peters et al., 1986). Our results indicate that warm alfalfa extracts, in general, increase the toxicity effects on weed species studied. One might speculate that hot extracts destroy some of the allelochemicals, while cold extracts may not allow the allelochemicals to be released as readily as warm extracts.

Inhibition of seed germination and seedling growth of lambsquarters, pigweed, velvetleaf, giant foxtail, cheatgrass, and crabgrass by alfalfa residue may be due to al-

Table 1. Germination inhibition of six weed species as affected by alfalfa forage extracts at five concentrations and three temperatures.

Weed species	Method	Germination inhibition, by extract conc., %				
		0	15	30	45	60
		%				
Lambsquarters	Hot	0a†	7a	14a	22a	28a
	Cold	0a	7a	15a	26a	34b
	Warm	0a	16b	28b	36b	44c
Pigweed	Hot	0a	6a	9a	18a	31a
	Cold	0a	10a	21b	26b	36b
	Warm	0a	21b	26b	33c	41c
Velvetleaf	Hot	0a	7a	14a	24a	31a
	Cold	0a	6ab	13a	28ab	35a
	Warm	0a	13b	24b	33b	42b
Giant foxtail	Hot	0a	4a	10a	17a	22a
	Cold	0a	4a	11a	22ab	29ab
	Warm	0a	10b	14a	28b	38b
Cheatgrass	Hot	0a	5a	12a	18a	29a
	Cold	0a	6a	14ab	22a	31a
	Warm	0a	15b	22b	32b	45b
Crabgrass	Hot	0a	2a	8a	15a	29a
	Cold	0a	5a	15b	26b	35ab
	Warm	0a	14b	23c	33b	40b

† Within columns and weed species, means followed by the same letter are not significantly different at the 0.05 level as determined by least significant difference (LSD).

Table 2. Root, shoot, and total seedling length inhibition of six weed species as influenced by aqueous extracts of alfalfa forage at warm temperature and five concentrations.

Weed species	Method	Length inhibition, by conc., %				
		0	15	30	45	60
		%				
Lambsquarters	Root	0a†	20b	38c	55d	67e
	Shoot	0a	23b	25b	33c	43d
	Total	0a	21b	32c	45d	56e
Pigweed	Root	0a	18b	42c	54d	69e
	Shoot	0a	16b	16b	21b	22b
	Total	0a	18b	33c	38c	48d
Velvetleaf	Root	0a	33b	50c	60d	71e
	Shoot	0a	4a	14b	18b	43c
	Total	0a	18b	34c	41d	58e
Giant foxtail	Root	0a	10b	31c	36d	36d
	Shoot	0a	7ab	12b	12b	14b
	Total	0a	8b	22c	25c	27c
Cheatgrass	Root	0a	15b	31c	40d	46e
	Shoot	0a	7b	10bc	15c	13bc
	Total	0a	12b	21c	28d	30d
Crabgrass	Root	0a	29bc	26b	35c	43d
	Shoot	0a	6a	22b	24b	25b
	Total	0a	18b	25c	30cd	33d

† Within rows and weed species, means followed by the same letter are not significantly different at the 0.05 level as determined by least significant difference (LSD).

lelopathic characteristics of alfalfa. Studies by Waller (1989) and Abdul-Rahman and Habib (1989) support the observation of the allelopathic effect of alfalfa on weed germination. They found saponins, caffeic, chlorogenic, isochlorogenic, *p*-coumaric, and ferulic acids present in alfalfa root exudates and residues.

Seedling Growth Study

Root length was significantly inhibited as the extract concentration rate increased except for giant foxtail between the 45 to 60% concentration (Table 2). The greatest root length reduction percentage was observed as 69% for pigweed and 71% for velvetleaf at the maximum concentration rate (60%). The greatest shoot length reduction (43%) was observed with lambsquarters and velvetleaf at 60% extract concentration (Table 2). Giant foxtail and pigweed shoot length did not decrease as extract concentration increased over the 15 to 60% range in concentration. Since root growth seems to be more sensitive than shoot or total seedling length, recording root length might be the most effective and also the quickest measurement when determining allelopathic effects of alfalfa extracts.

The linear regression equation of total seedling length and extract concentration was significant at the 0.001 probability level, while there was no significant fit for quadratic or cubic equations (Table 3). Lambsquarters (b = 0.049) had the highest slope value, followed by velvetleaf (b = 0.044), demonstrating more susceptibility to alfalfa aqueous extracts than other species tested. Residual analysis demonstrated normality of residuals and no trends appeared on residuals versus predicted data. Giant foxtail (b = 0.029) was the most tolerant weed species tested, based on regression slope analysis.

Effect of Incubation Time on Seed Germination

In most cases, increasing the incubation time of dry alfalfa residue inhibited the germination percentage of six of the weed species (the exceptions were lambsquarters, foxtail, and crabgrass) when incubation increased from 24 to 48 h (Table 4). This is in agreement with results from Patrick and Koch (1958), Al-Naib and Rice (1971), and Kuo et al. (1981). Patrick and Koch (1958) reported that phytotoxic substances may be released during residue decomposition in the soil. The greatest reduction in seed germination occurred with velvetleaf, crabgrass, and pigweed when alfalfa residue was subjected to a 48 h incubation period before the germination test.

The decrease of weed seed germination with incubation time may be due to a release of more water-soluble toxic substances from decomposing plant tissue or to the formation of toxic chemicals by microorganisms during residue decomposition (Barnes and Putnam, 1983; Harrison and Peterson, 1986). Our results differ from those of Patrick et al. (1963) and Guenzi et al. (1967), who found that toxic effects of plant residues generally decrease as decomposition progresses. Thus, plant species and some cultivars respond differently to phytotoxic substances.

Table 3. Total seedling length of six weed species as a function of increasing alfalfa aqueous extracts by different concentrations (15, 30, 45, and 60%).

Weed species	Regression equation $Y = a + bx$	R^2
Lambsquarters	5.23 − 0.049x	0.96***
Pigweed	5.31 − 0.042x	0.80***
Velvetleaf	4.67 − 0.044x	0.97***
Giant foxtail	6.05 − 0.029x	0.82***
Cheatgrass	6.93 − 0.037x	0.91***
Crabgrass	5.76 − 0.032x	0.81***

*** Linear effect significant at the 0.001 probability level.

Greenhouse Study

The influence of incorporation of alfalfa residue into silica sand and the reduced growth and development of lambsquarters, pigweed, and velvetleaf weed plants suggested that toxic compounds are released from alfalfa residues or produced by microorganism activity during residue decomposition (Table 5). In general, the higher the residue application rate, the greater the growth inhibition. This inhibition may be due to a greater release of phytotoxic substances by interaction between residues and microorganisms. However, this conclusion has to be studied more carefully, as several factors are involved in allelopathic activity. Microbial activity was not investigated in this study. The greatest reduction in total dry weight increase was observed in velvetleaf. Total dry weight inhibition range was from 15 to 79% at the 0.5 to 2.0% residue rate levels, respectively (Table 5).

Allelochemicals released or produced from residue interfere with cell division and cell elongation. Reduced root cell growth may decrease mineral nutrient uptake, including reduced root area, nutrient absorption capacity, the active ion transport mechanisms, and finally reducing the transport of nutrients from the roots to other plant parts (Buchholtz, 1971). Thus, a relatively small root system has to supply large aboveground parts with mineral nutrients and water, as evidenced in Table 5. Changes in biomass partitioning or distribution into plant parts could explain the observed difference in the reduced weed growth.

Unlike lambsquarters, velvetleaf and pigweed, the plant height, leaf area, and total dry weight (including shoot, leaf, and root) of giant foxtail and cheatgrass were enhanced by dry alfalfa as the residue rate increased (Table 5). Giant foxtail total dry weight stimulation ranged from 30% at the 0.5% residue rate to 94% at the 2.0% residue rate.

Giant foxtail and cheatgrass growth and development may be related to the stimulatory effects of allelochemicals (Table 5). Allelochemicals can stimulate or inhibit plant growth, depending on the concentration (Osvald,

Table 4. Germination inhibition of six weed species over four different incubation times by dried alfalfa forage at 24°C.

Species	Germination inhibition, by incubation time, h				
	0	8	16	24	48
	%				
Lambsquarters	0a†	5ab	9b	19c	21c
Pigweed	0a	1a	6a	15b	24c
Velvetleaf	0a	2ab	7b	17c	25d
Giant foxtail	0a	1a	4a	13b	14b
Cheatgrass	0a	2a	10b	13b	22c
Crabgrass	0a	6a	8a	23b	23b

† Within rows, means followed by the same letter are not significantly different at the 0.05 level as determined by least significant difference (LSD).

Table 5. Effect of alfalfa residues on height, leaf area, and shoot, leaf, root, and total dry weight of six weed species grown in sand culture.

Residue level (w/w)	Plant height, cm	Leaf area, cm^2	Dry weight, mg			
			shoot	leaf	root	total
	% change					
			Lambsquarters			
0.0	0a†	0a	0a	0a	0a	0a
0.5	−14b	−37b	−26b	−45b	−52b	−45b
1.0	−19b	−45c	−41c	−55b	−57b	−54c
1.5	−34c	−51d	−51c	−70c	−62c	−64d
2.0	−34c	−57e	−68d	−74c	−68d	−71e
			Pigweed			
0.0	0a†	0a	0a	0a	0a	0a
0.5	−12b	−43b	−44b	−38b	−39b	−39b
1.0	−24c	−64c	−60c	−60c	−73c	−65c
1.5	−39d	−75d	−68c	−67c	−78cd	−71d
2.0	−42d	−82e	−84d	−81d	−84d	−83e
			Velvetleaf			
0.0	0a†	0a	0a	0a	0a	0a
0.5	−25b	−20b	−14b	−16b	−13b	−15b
1.0	−37c	−34c	−47c	−28c	−29c	−36c
1.5	−48d	−59d	−79d	−70d	−68d	−74d
2.0	−55d	−75e	−83d	−75d	−76d	−79e
			Giant foxtail			
0.0	0c†	0d	0d	0d	0e	0e
0.5	+2c	+9c	+20c	+9d	+25d	+30d
1.0	+6c	+14c	+31c	+14c	+38c	+54c
1.5	+23b	+28b	+60b	+26b	+73b	+64b
2.0	+36a	+51a	+85a	+51a	+89a	+94a
			Cheatgrass			
0.0	0c†	0d	0d	0d	0d	0d
0.5	+6b	+16c	+14cd	+29cd	+30cd	+12c
1.0	+11b	+28b	+26bc	+39cd	+21c	+39c
1.5	+17a	+35b	+41b	+75b	+58b	+68b
2.0	+19a	+71a	+85a	+94a	+96a	+99a
			Crabgrass			
0.0	0a†	0b	0b	0b	0b	0b
0.5	0a	+5a	+71a	+25a	+42a	+40a
1.0	−6b	−2c	−26c	−4b	−5c	−7c
1.5	−10bc	−33d	−32d	−33c	−28d	−29d
2.0	−12c	−34d	−45e	−37c	−47e	−45e

† Within columns and weed species, means followed by the same letter are not significantly different at the 0.05 level as determined by least significant difference (LSD).

1950). Ries et al. (1977) reported that coarsely chopped alfalfa hay increased tomato (*Lycopersicon esculentum* Mill.) growth and yield when placed in a band below and to the side of seeds or seedlings. Thus, differential action including both inhibitory and stimulatory relationships would be expected in the field, depending on the amount of allelochemicals and the test species.

Crabgrass growth pattern responded differently to residue levels, as compared with giant foxtail and cheatgrass (Table 5). The total dry weight of crabgrass increased by 40% at the lowest residue rate (0.5%), compared with control. As the residue rate increased, total dry weight increase was significantly inhibited by 45% at the highest residue level. This result is similar to that of Osvald (1950), who showed that dried stolons and roots of quackgrass [*Elytrigia repens* (L.) Nevski] strongly inhibited rape (*Brassica napus* L.) and oat germination at high extract concentrations, while germination was stimulated at low concentrations.

The growth inhibition and stimulation response to aqueous extracts was rate dependent; maximum growth inhibition and stimulation resulted at the highest residue rate (2.0%). In addition, growth and development of dicotyledonous weeds such as pigweed, lambsquarters, and velvetleaf were inhibited by an increase in the alfalfa residue rate, while the growth and development of monocotyledons like giant foxtail and cheatgrass were stimulated at the 0.5% residue level of alfalfa. Thus, there appears to be a relationship among dicotyledonous species that may have, or release, similar allelochemicals.

These results demonstrate the species-specific growth regulatory effects of allelochemicals. It is apparent from these results that the reduction of seed germination and seedling growth of selected weed species and reduction or stimulation of growth and development in selected weed species was due to allelochemicals released from alfalfa. This result points to the possibility that allelochemicals released by alfalfa may stimulate the growth of monocotyledonous weed species. The results of this study support previous conclusions by various researchers (Fay and Duke, 1977; Leather, 1983; Rose et al., 1984; Abdul-Rahman and Habib, 1989) that alfalfa may have potential as an allelopathic weed control.

One limitation of this study is that the concentration of toxic substances is greater than would be found in nature, and the duration of toxic substances contained in the residue or released from their decomposition may be shorter under field conditions. This study shows, however, that inhibitory substances present in alfalfa plants should be tested as a potential natural herbicide resource.

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