Journal of Chemical Ecology, Vol. 9, No. 8, 1983

ALLELOPATHIC EFFECTS OF ALFALFA

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(Received September 12, 1982; revised November 9, 1982)

Abstract—Several experiments have been conducted at the University of Illinois, Urbana, Illinois, to determine the role of allelopathic (autotoxicity) effects of alfalfa (*Medicago sativa* L.) on the establishment of alfalfa. By means of correcting any soil fertility differences and protecting the alfalfa seedlings from fungal attack, results suggest that there is a release of phytotoxic factors from the previous crop on reestablishing alfalfa. Field results indicate that the best preceding crop for alfalfa establishment is corn (*Zea mays* L.), followed by various small grains, soybeans (*Glycine max* L.), and the worst preceding crop is alfalfa. Results indicate there were no major genetic differences among cultivars for resistance to autotoxicity. There was no evidence supporting saponins as being phytotoxic to alfalfa. Exudates of different saponin level cultivars indicated that saponin content is not the suspected phytotoxic factor.

Key Words—Allelopathy, autotoxicity, establishment, *Medicago sativa* L., *Zea mays* L., *Glycine max* L., small grains, saponins, alfalfa yields.

INTRODUCTION

In the past, plant interactions have been explained in physical terms by assuming that competition for light, space, water, and nutrients were the major factors. More careful measurements tend to suggest that many plants are given selective advantage by means of allelopathic activity. Allelopathy is any direct or indirect harmful effect by one plant on another through the production of chemical compounds that escape into the environment (Rice, 1974).

One of the most studied areas of allelopathy is its role in old field succession and other natural ecosystems (Rice, 1974). In recent years, allelopathy has been implicated in agricultural situations as well. Due to the increased interest in various agricultural systems where plant interactions are critical, knowledge of allelopathy has become a necessity. These systems include interplanting, double cropping, conservation tillage, and limited or nonrotational cropping.

Alfalfa (*Medicago sativa* L.), a long-lived perennial, is one of the most important legumes used for livestock feed and soil improvement. Under limited rotation of cropping in central Alberta, Canada, alfalfa was difficult to reestablish (Webster et al., 1967). Typical plant symptoms in the field were: dwarfed, spindly, yellowish green plants with irregular brown–reddish to dark-brown lesions on the tap and lateral roots and a few ineffective nodules (Webster et al., 1967).

Results of field and greenhouse studies (Webster et al., 1967; Webster and DeKock, 1969) indicate that neither macro- nor micronutrient deficiencies were responsible for the stunted growth of alfalfa. Steam sterilization or sterilization with vapam and gamma radiation increased alfalfa yields, suggesting that the inhibitory factor was biotic. Aqueous extracts from affected soils added to alfalfa growing in sand culture significantly reduced the yield (Webster et al., 1967).

Nielsen et al. (1960) investigated the effects of aqueous extracts of alfalfa hay (50% bloom), timothy hay (50% bloom), and mature corn stover, oat straw, and potato vines on seed germination and seedling growth of corn (*Zea mays* L.), soybeans (*Glycine max* L.), peas (*Pisum sativa* L.), oats (*Avena sativa* L.), alfalfa (*Medicago sativa* L.), and timothy (*Phleum pratense* L.). Alfalfa caused the greatest delay in germination of all test species except one; the germination of timothy was delayed the longest with timothy extract. Thus, Nielsen definitely demonstrated that certain crop plants (especially alfalfa) contain water-soluble materials that inhibit seed germination and seedling growth of several crop plants.

In Nebraska (Guenzi et al., 1964), it was found that alfalfa contains water-soluble substances toxic to itself and to other plants, and water extracts of immature alfalfa forage had the highest phytotoxic effects on corn seedlings in a laboratory study. Soil incorporation of young alfalfa forage from old plants while interseeding alfalfa to thicken old stands may introduce water-soluble substances toxic to new alfalfa seedlings.

Guenzi et al. (1964) had implicated saponins as being a possible water-soluble phytotoxic substance released by alfalfa forage. Aqueous solutions of alfalfa root saponin have been shown to inhibit the germination of cotton seeds (Marchaim et al., 1975). However, aqueous extracts of alfalfa root saponin did not inhibit the germination of alfalfa.

Work at Illinois (Klein and Miller, 1980) indicated that alfalfa was difficult to reestablish without rotating to another crop first. When alfalfa was plowed in the fall and reseeded with alfalfa the following spring, yield and stand count decreased each year. The yield and stand counts of alfalfa in the single cropping situation were markedly lower than when rotated with either corn or corn and soybeans. Pathologists concluded that pathogen infestation could not account for these results.

The purpose of the present investigations was to gain information on the factors responsible for the difficulties in reestablishing a weakened stand of alfalfa and to determine whether such problems are related to improper management, plant diseases, soil fertility, or to the release of phytotoxic substances by alfalfa. If the reestablishment problem could be attributed to autotoxic substances, we hoped to determine whether genetic tolerance for the toxic factor existed, and whether saponins were the toxic factor. A further purpose was to determine whether phytotoxic substances, exuded from fall dormant cultivars, along with the proper environmental stimuli (cold nights and short days) would result in fall dormancy.

METHODS AND MATERIALS

Experiment One. Two sites at the University of Illinois, Urbana-Champaign, Agronomy South Farm were selected for conducting experiment 1. The two sites were separated by a distance of approximately 300 m. At one site an alfalfa variety trial had been conducted the previous five years, while the second site had been planted in soybeans in 1975 and corn in 1976. Soil type at the former alfalfa site was an Aquic Argiudolls, fine, montmorillonite, mesic, while the soil at the corn–soybean site was an Aquic Arguidolls, fine, silty, mixed mesic. The seedbed of each site was prepared with a corrugated field roller producing firm seedbeds. Seeds of the cultivars listed in Table 1 were planted May 12, 1977. The cultivars were mechanically broadcast on plots 152 × 366 cm at the rate of 20 kg/hectare.

Plant populations (plants/meter^2) were determined June 14, 1977; September 8, 1977; and subsequent to the first harvest in 1978. Populations were based on the number of plants in a 1-m^2 area. Three population samples were taken per plot, with one sample taken at each end and one toward the middle of the plot. Forage harvests were scheduled when the alfalfa was $\frac{1}{10}$ to $\frac{1}{2}$ bloom. The center 92 cm of each plot was harvested and dry matter yields determined. Harvest dates were September 19, 1977; June 6, 1978; and August of 1978. Additional harvests were scheduled in 1978, but yield data were not recorded due to the weakened condition of the stands at both sites.

Soil pH, P, and K levels, carbon–nitrogen ratios, soil moisture, and the incidence of the diseases, *Phytophthora megasperma*, *Pythium* sp., and *Fusarium oxysporum*, were determined from soil samples from each site (Table 2). Pathogen incidence was determined by procedures employed by the University of Illinois Plant Clinic. Diseased seedlings were planted on both potato–dextrose agar and Schmidhenner's–water agar and were subsequently inspected for signs of the three mentioned diseases (Graham et al., 1979). The

TABLE 1. CHARACTERISTICS OF VARIOUS ALFALFA STRAINS, EXPERIMENT ONE

Strains[a]	Saponin content	Fall growth[b]
Ladak	Low	Pronounced fall dormancy
Ladak	High	Pronounced fall dormancy
Uinta	Low	Slight fall dormancy
Uinta	High	Slight fall dormancy
DuPuits	Low	Slight fall dormancy
DuPuits	High	Slight fall dormancy
Ranger	Low	Moderate to pronounced fall dormancy
Ranger	High	Moderate to pronounced fall dormancy
BWR synthetic	Low	[c,d]
BWR synthetic	High	[c,d]
Saranac AR	[c,d]	Moderate to pronounced fall dormancy
Vernal	[c,d]	Pronounced fall dormancy

[a]Seed source: M.W. Pedersen, Logan, Utah.
[b]Fall growth characteristics according to Smith (1975).
[c]Not included in comparative trials.
[d]Information not available.

percentage of seedlings exhibiting signs of any of the three diseases was recorded. Soil moisture was determined by weighing the soil samples, placing them in an oven at 100° C for 65 hr, and reweighing.

In the spring of 1978, 272 kg/hectare of P_2O_5 and 710 kg/hectare of K_2O were applied to the alfalfa variety trial site and 141 kg/hectare of P_2O_5 and 471 kg/hectare of K_2O were applied as a top dressing to the soybean-corn site.

The insecticide Sevin was applied at a rate of 454 kg/hectare active ingredient one week after each harvest.

Prior to the first harvest in 1977, substantial grass and broadleaf weed infestation occurred at both sites. Hand cultivation and the grass herbicide Dowpon M were employed to control weed infestation. Dowpon M was applied June 30, 1977, as a postemergence treatment at a rate of 2270 kg/hectare at 84% active ingredient. Both sites were irrigated July 17, 1977, with approximately 3.8 cm of water.

Experiment Two. A site was selected at the University of Illinois Agronomy South Farm on which forage management practices had been investigated the previous four years. Soil type at this site was Aquic Argiudolls, fine, silty, mixed mesic. In 1974, eight tiers were planted—three were solid seeded to Vernal alfalfa, one to a smooth brome–Vernal alfalfa mixture, and four were planted in forage grasses, resulting in a stand density of 43%, 32%, and 21% alfalfa. Various cutting schedules were conducted on the eight tiers resulting in forage stands of varying densities and levels of weed infestation.

TABLE 2. SOIL TEST RESULTS FOR SOIL SAMPLED FROM ALFALFA VARIETY TRIAL AREA AND SOYBEAN-CORN ROTATION AREA, EXPERIMENT ONE[a]

Area	pH	P_i test (kg/hectare)	K test (kg/hectare)	C-N ratio	Soil moisture (%)	Pathogen incidence (%)
Alfalfa variety trial	6.40 ± 0.15	58.6 ± 15.4	247.7 ± 36.3	12.4 ± 0.5	17.1 ± 2.2	5.5 ± 0.04
Soybean-corn rotation	6.65 ± 0.15	54.7 ± 15.4	261.4 ± 36.3	12.3 ± 0.5	21.2 ± 2.2	3.8 ± 0.04

[a] Mean values and standard errors presented, $N = 12$.

Soil samples were collected from the site and tested as described in experiment 1. Prior to seeding, maintenance and build-up of P and K fertilizers were applied according to accepted guidelines. The herbicide Tolban was applied as a preplant treatment at a rate of 2.3 liters/hectare to control grassy weeds. The seedbed was prepared in the same manner as in Experiment 1. Cultivars Vernal, WL318, and WL306 were treated with captan and subsequently planted June 15, 1978, in 152 × 457-cm plots. The plots were positioned within the boundaries of the previous year's cutting treatments (tiers). The broadleaf herbicide, 2,4D-B, was applied as a postemergence treatment at an accepted rate prior to the first harvest in 1978. Plots were irrigated on June 15 and 16 with approximately 2.5 cm of water each day.

Seedling stand densities per square meter were recorded June 27, 1978. Forage harvest dates were September 28, 1978, and May 31 and August 15, 1979. One week after each harvest, the insecticide Sevin was applied.

Prior to the first harvest in 1978, heavy grass infestation occurred. Hand cultivation was employed to control the grass.

Statistical Analyses. The experimental designs for the two experiments were: (1) experiment 1 was a randomized complete block design for both the former alfalfa area and the soybean–corn rotation area with five replicates in 1977 and four remaining in 1978; and (2) experiment 2 was conducted as a randomized complete block design for each of the eight tiers with four replicates per tier. A combined analysis over areas (or tiers) was conducted for each experiment, to determine the significance of rotational differences and the significance of the interaction of the cultivars with rotations. For experiment 2, the following rotation (tier) comparisons were made: (1) the linear and quadratic effects of stand density of the previous alfalfa crop; and (2) the comparison of those tiers formerly established in alfalfa versus those tiers formerly established in forage grasses.

A stepwise regression procedure was used for experiment 1 to explain the variation in alfalfa performance among those plots from which soil was sampled June 15, 1977. Independent variables used in the equations were: soil pH, P and K levels, pathogen incidence, C–N ratios, and the location itself. Cultivar effects were not included in the regression procedure since plots of all the cultivars were not sampled. However, an equal number of plots of the selected cultivars were sampled from each field to eliminate any cultivar-location confounding. Variation associated with the location may include rotation differences or other confounding factors. A model was selected to best explain the variation in plant population and dry matter yields among the sampled plots.

Experiment Three. Soil samples were collected from 13 sites within each of the two field locations of field experiment 1. Soil sampling sites within each location were: (1) the root zones of the 12 alfalfa strains planted in 1977 at each location (Table 1), and (2) the fallow area for each location.

Eight to 10 plants of each strain were excavated and the soil from the root zone of each plant recovered and placed into separate, labeled containers. Fallow soil was collected in similar manner from both locations. Soil was allowed to air dry in a greenhouse for four months. Soil pH, phosphorus, and potassium were determined for the soil samples. On January 26, 1978, 15 rhizobial-inoculated seeds of Vernal alfalfa were sowed in each pot at a depth of 2 mm. A 1-cm layer of quartz sand mulch covered the sand. A 300-ml solution of the fungicide Shield was applied immediately after planting. Subsequently, Shield was applied at three-day intervals until 50% of the seedlings were at the first trifoliate leaf stage.

Percent emergence was recorded 4 and 16 days after planting. Seedling height measurements were obtained 20 days after planting. Heights of individual seedlings were measured from the cotyledonary node to the first trifoliate leaf node. Densities were then reduced to four plants per pot. At 60-day intervals, leaves and shoots were harvested three times and oven-dried at 60° C for at least 48 hr prior to weighing.

Following each harvest, a solution of KH_2PO_4 was added to the soil in each pot to build up K and P to levels required for alfalfa growth. The amount of maintenance KH_2PO_4 to be applied was based on the quantity of K removed per pot rather than P, since greater quantities of K are removed per unit dry matter of alfalfa (Smith, 1975).

Diurnal temperature limits of 15/32° C and 16 hr of light were provided throughout the length of the experiment. Supplemental radiation was supplied by fluorescent tubes and incandescent bulbs.

The experiment was designed as a 2 × 13 factorial in a randomized complete block design with three replicates. The factors were: (1) the two locations from which soil was collected—locations cropped in alfalfa (1972–1976) or cropped in soybeans (1975) and corn (1976); and (2) the 13 excavation sites within each location—sites including the fallow area and the root zones of the 12 strains planted in 1977 at each location. The phytotoxic properties of the following soils were compared: (1) root zone soil of high saponin versus low saponin alfalfa strains; (2) root zone soil of fall dormant versus slightly fall dormant alfalfa strains; (3) root zone versus the fallow soils; and (4) soil cropped in alfalfa during the period from 1972 to 1976 versus soil cropped in soybeans in 1975 and corn in 1976.

RESULTS

Experiment One. Plant populations and dry matter yields were consistently greater where alfalfa was grown in rotation with corn and soybeans

TABLE 3. DRY MATTER YIELDS AND PLANT POPULATIONS OF ALFALFA IN TWO ROTATION SEQUENCES

Rotation sequence	Plant population (plants/m^2)			Yield (metric tons/ha)		
	6/14/77	9/8/77	6/6/78	9/19/77	6/6/78	9/15/78
Alfalfa–alfalfa	61.5	23.8	16.7	1.52	3.57	2.47
Soybean–corn–alfalfa	90.4	29.8	22.3	2.24	4.29	3.04
Difference	−28.9**[a]	− 6.0**	− 5.6**	−0.74**	−0.72**	−0.57**

[a] **Significant, based on one-tailed *T* test, at the 0.05 level.

(Table 3). Populations and dry matter yields differed among the cultivars. These differences were similar for both rotation sequences except for the August harvest date. August yields of most cultivars were slightly greater for the soybean–corn–alfalfa rotation (Table 4). The exceptions were Vernal alfalfa which yielded essentially the same for both rotations, and DuPuits (low saponin) and BWR syn (low saponin) alfalfa which yielded substantially less in the continuous cropping situation.

The regression models selected by the stepwise regression procedure are presented in Table 5. Seventy-five percent of the variation in seedling populations was attributable to four independent variables: soil pH, soil P,

TABLE 4. DRY MATTER YIELDS (METRIC TONS/HECTARE) OF 12 ALFALFA CULTIVARS FOR TWO ROTATION SEQUENCES.

	Rotation sequence	
	Alfalfa–alfalfa[a]	Soybean–corn–alfalfa[a]
Ladak (low saponin)	1.8	2.5
Ladak (high saponin)	2.6	2.9
Uinta (low saponin)	2.6	3.2
Uinta (high saponin)	2.4	3.1
DuPuits (low saponin)	1.6	2.6
DuPuits (high saponin)	2.1	2.7
Ranger (low saponin)	2.5	3.1
Ranger (high saponin)	2.9	3.1
BWR syn. (low saponin)	2.3	3.6
BWR syn. (high saponin)	2.8	3.3
Saranac AR	3.1	3.6
Vernal	3.0	3.0

[a] Metric tons per hectare.

TABLE 5. INDEPENDENT VARIABLES SELECTED BY STEPWISE REGRESSION PROCEDURE AND CORRESPONDING PROPORTION OF VARIATION ACCOUNTED FOR BY VARIABLES, EXPERIMENT ONE[a]

Dependent variable	Soil factors							Location (rotation)	
	pH	P	K	C–N ratio	Moist.	Path.	R^b(%)		R^b(%)[c]
Plant pop. (6/77)	x	x				x	46.5	x	26.3
Plant pop. (9/77)						x	16.5		
Plant pop. (6/78)						x	29.5	x	31.0
Yield (9/77)								x	62.2
Yield (6/78)	x						34.2		
Yield (9/78)								x	32.1

[a] Marks under a given factor indicate selection by the stepwise regression procedure.
[b] The proportion of the variation attributable to the soil factors selected by the stepwise regression procedure.
[c] The proportion of the variation attributable to location (rotation) after adjusting for the selected soil factors.

pathogen incidence, and location. The location effect, which may be the result of a difference in rotation sequence, accounted for 26% of the variation in seedling population.

A mere 16% of the variation in the fall of 1977 alfalfa populations was accounted for by soil pathogen incidence (Table 5). No other independent variable accounted for a significant percentage of the variation. In contrast, soil pathogen levels and location together accounted for nearly 61% of the variation in 1978 plant populations with location accounting for 31% of that. Sixty-two percent of the variation in 1977 yields and 32% of the variation of the September 1978 yields can be assigned to locations with none of the other independent variables accounting for an appreciable amount of the variation. In contrast, the location did not account for a significant percentage of the variation of the June 1978 yields, while soil pH was able to account for 34%.

Experiment Two. Seedling populations and 1979 yields increased as stand densities of the previous alfalfa crop increased from 21 to 32% and subsequently decreased as previous stand densities increased from 32 to 43%. In contrast, there was a linear increase in 1978 yield as stand densities of the previous alfalfa crop increased.

The three cultivars, WL306, WL318, and Vernal, responded similarly to the change in stand density of the previous alfalfa crop.

Seedling populations and 1979 yields were greater where the previous crop was a forage grass rather than alfalfa (Table 6). However, dry matter yields in 1978 were similar for those tiers previously established in forage grasses and alfalfa. The response to the type of forage species previously established was similar for the three cultivars tested.

Experiment Three. Early growth of Vernal alfalfa was generally more

TABLE 6. ALFALFA DRY MATTER YIELDS AND SEEDLING POPULATIONS UNDER TWO ROTATION SEQUENCES, EXPERIMENT THREE

Rotation sequence	Seedling populations (plants/m^2)	Dry matter yields (metric tons/hectare)		
		9/78	5/79	8/79
Alfalfa–alfalfa	171.9	2.0	5.0	4.6
Forage grasses–alfalfa	197.4	2.2	5.5	5.3
Difference	− 25.5*[a]	−0.2	−0.5*	−0.7*
Average	184.6	2.1	5.2	5.0

[a] *Significant, based on one-tailed T test, at the 0.05 level.

TABLE 7. PERCENTAGE OF EMERGENCE OF VERNAL ALFALFA, FOUR TO SIXTEEN DAYS AFTER PLANTING

Previous crop	Percentage of emergence (days after planting) 4	16
Soybean (1975)-corn (1976)		
Root zone average	76.6	80.1
Fallow soil	95.6	93.3
Difference	−19.0**[a]	−13.2*
Overall average	77.8	79.8

[a] *, **Significant, based on one-tailed T test, at the 0.1 and 0.05 levels, respectively.

vigorous in the fallow soil as compared to the root zone soil previously cropped in soybeans (1975) and corn (1976). Percentage of emergence (Table 7), seedling height (Table 8), and first harvest yields (Table 9) were greater in the fallow soil. Soil potassium and phosphorus levels were also substantially higher in the fallow soil previously cropped in soybeans (1975) and corn (1976).

TABLE 8. SEEDLING HEIGHTS OF VERNAL ALFALFA 20 DAYS AFTER PLANTING

Previous crop	Seedling height (mm)
Soybean (1975)-corn (1976)	
Root zone—fall dormant	18.8
Root zone—slight fall dormant	21.9
Difference	− 3.1*[a]
Root zone average	21.2
Fallow soil	32.6
Difference	−11.4*
Alfalfa (1972–1976)	
Root zone average	15.5
Fallow soil	19.6
Difference	− 4.1*
Soybean (1975)-corn (1976) average	22.1
Alfalfa (1972–1976) average	15.8
Difference	6.3*
Overall average	18.9

[a] *Significant, based on one-tailed T test, at the 0.05 level.

TABLE 9. DRY MATTER YIELD OF VERNAL ALFALFA HARVEST 60, 90, AND 120 DAYS AFTER PLANTING

Previous crop	Dry matter yield (g) (days after planting) 60	90	120
Soybean (1975)–corn (1976)			
Root zone average	0.22	2.01	15.64
Fallow soil	0.46	2.54	16.03
Difference	−0.24*	−0.53*	− 0.39
Alfalfa (1972–1976)			
Root zone—low saponin	0.17	1.58	13.37
Root zone—high saponin	0.19	1.99	15.24
Difference	−0.02	−0.41*	− 1.87
Soybean (1975)–corn (1976) average	0.19	1.81	14.45
Alfalfa (1972–1976) average	0.24	2.05	15.67
Difference	−0.05*	−0.24*	− 1.22
Overall average	0.21	1.92	14.96

[a] *Significant, based on one-tailed T test, at the 0.05 level.

Except for seedling height differences, the growth of Vernal alfalfa was similar in the root zone and fallow soils previously cropped in alfalfa. Soil potassium and phosphorus levels were higher in the fallow soil but the magnitude of the difference was not as great as was observed for the soils previously cropped in soybeans and corn. Later stages of alfalfa growth were similar in the root zone and fallow soils.

The growth of Vernal alfalfa in the root zone soils of high and low saponin strains was similar except for second harvest yields. Second harvest yields were greater for root zone soils of high saponin strains previously cropped in alfalfa (1972–1976) (Table 9). Soil phosphorus levels were slightly higher for the root zone soil of high saponin strains while potassium levels were essentially the same.

Except for seedling height differences, the growth of Vernal alfalfa was similar for the root zone of fall dormant and slightly fall dormant strains. Seedlings were approximately 3 mm taller in root zone soils of slightly fall dormant strains. Height differences were observed only for soil previously cropped in alfalfa. Soil K levels were substantially higher for the root zone soils of slightly fall dormant strains.

Seedling height alone with first and second harvest yields differed for soil previously cropped in alfalfa (1972–1976) and soil previously cropped in soybeans (1975) and corn (1976). Height and yield were greater for the soil previously cropped in soybeans and corn (Tables 8 and 9). Soil P and K levels were substantially greater for those soils previously cropped in soybeans and corn.

DISCUSSION

Alfalfa yields and stand densities were greater where alfalfa was rotated with soybeans and corn, compared with continuous cropping of alfalfa. A considerable portion of the variation in alfalfa performance was attributable to soil fertility, pH, and soil pathogen incidence. Results tend to suggest that some of the variation in alfalfa performance was attributable to the release of phytotoxic factors from the previous alfalfa crop.

When P and K deficiencies were corrected and alfalfa seedlings were protected against fungal attack, seedling emergence was still poorer with the continuous cropping of alfalfa. Having eliminated disease and P and K deficiencies as probable causes, phytotoxic factors are strongly implicated as the cause of the reestablishment difficulties. Second year dry matter yields for experiment 2 were substantially lower when alfalfa was grown following alfalfa. Differences in second-year yields may be due to the release of phytotoxic factors by the previous alfalfa crop.

In general there were no detectable cultivar–rotation interactions. It would appear that genetic differences among cultivars in response to this trait do not exist. These results are in agreement with those of Goplen and Webster (1969) which indicate that genetic selection against the suspected toxic soil factor was ineffective. A selection program may be unsuccessful unless more definitive information on the cause of this problem can be discovered.

Even though the results are not conclusive, alfalfa seedling establishment was more successful where alfalfa had not been grown for at least two years. The difficulty in reestablishing alfalfa without rotating may be ascribed to the accumulation of phytotoxic substances. Another possible explanation is soil fertility deficiencies due to the heavy feeding of P and K by the previous alfalfa crop. The differences in seedling growth between the root zone soils of fall dormant and slightly fall dormant alfalfa would tend to suggest an involvement of phytotoxic factors associated with fall dormancy.

There is little evidence to support saponins as being phytotoxic to alfalfa. While various studies indicate that they are toxic to cotton, they apparently are not toxic to alfalfa (Marchaim et al., 1975). This interpretation is based on the assumption that saponins are released from alfalfa tissue in proportion to their tissue content. It is known that saponins are released by alfalfa roots (Leshem and Levin, 1978), but whether they are released in proportion to their tissue content is unknown.

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