Weed Control in Oat (*Avena sativa*)-Alfalfa (*Medicago sativa*) and Effect on Next Year Corn (*Zea mays*) Yield[1]

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Abstract. Field experiments were conducted from 1985 through 1989 to evaluate herbicide selectivity and impact on seeding-year yields of spring oat and underseeded alfalfa, and carryover weed control benefits from increased legume-fixed N for second-year dryland no-till corn. PRE metolachlor, pendimethalin, and prodiamine controlled green foxtail and POST bromoxynil or 2,4-DB controlled broadleaf weeds. These herbicides caused 0 to 20% alfalfa injury and 0 to 17% oat injury, and increased oat yield one of three years but did not increase the yield of underseeded alfalfa. POST pyridate, thifensulfuron, and tribenuron were too injurious to either oat, alfalfa, or both crops. Forage yields of annual 'Nitro' and perennial 'Wrangler' alfalfa seeded alone were greater than when they were underseeded in oat, with herbicides applied in both systems. As a result of drought in 1988 and 1989, yield of second-year corn planted after one-year alfalfa was not increased from potentially greater legume-fixed N. Dryland corn yield following monoculture oat or corn was 254% higher than corn following alfalfa. **Nomenclature:** Benefin, *N*-butyl-*N*-ethyl-2,6-dinitro-4-(trifluoromethyl)benzenamine; bromoxynil, 3,5-dibromo-4-hydroxybenzonitrile; metolachlor, 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide; pendimethalin, *N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine; prodiamine, 2,4-dinitro-N^3,N^3-dipropyl-6-(trifluoromethyl)-1,3-benzenediamine; pyridate, *O*-(6-chloro-3-phenyl-4-pyridazinyl) *S*-octyl carbonothioate; thifensulfuron, 3-[[[[4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylic acid; tribenuron, 2-[[[[4-methoxy-6-methyl-1,3,5-triazin-2-yl)methylamino]carbonyl]amino]sulfonyl]benzoic acid; 2,4-DB, 4-(2,4-dichlorophenoxy)butanoic acid; alfalfa, *Medicago sativa* L.; corn, *Zea mays* L.; green foxtail, *Setaria viridis* (L.) Beauv. #[3] SETVI; oat, *Avena sativa* L.

Additional index words: Companion seeding, cover crop, crop rotation, forage, solo seeding, pyridate, thifensulfuron, tribenuron, *Abutilon theophrasti*, ABUTH.

INTRODUCTION

Forage legumes were once commonly used in crop rotations as a N source. This use declined when low cost synthetic N fertilizers became available (22). The energy crisis of the 1970's caused renewed interest in legumes as a N source (17). The concept of agricultural sustainability includes conservation of natural resources and enhancement of environmental quality. Legume cover crops can play an important role in achieving the goals of sustainable agriculture (12). Currently, legumes are a more costly source of N than commercial fertilizers but other benefits of legume rotations should be figured into the calculation (1, 11, 17).

Nitro alfalfa was developed to supply forage and N in short-term rotations. The annual, nondormant Nitro provided 62% more symbiotically fixed N for plow-down than dormant cultivars (22). Enhanced root N fixation by Nitro was agronomically significant only when established without competition from weeds or a small grain crop (23). Hesterman et al. (11) compared crop rotations including both Nitro and perennial 'Saranac' alfalfa, soybean [*Glycine max* (L.) Merr.], and corn. An alfalfa-corn rotation with alfalfa managed in a three-cut system was the economically optimum rotation.

Spring-seeded oat is a multipurpose crop in the North Central states. It is seeded with alfalfa to be used for extended forage production or to improve soil properties. Oat was the companion crop of choice by 87% of the respondents to a Minnesota survey, whereas spring barley (*Hordeum vulgare* L.) and spring wheat (*Triticum aestivum* L.) were selected by 22% and 8%, respectively (24). Soil protection was the primary rea-

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[3]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.

son for planting a small grain with a forage legume; production of grain, straw, or additional forage by the companion crop, or suppression of weeds was of lesser importance. Barley cultivars competed with alfalfa more than oat cultivars and lodged more frequently (5).

Herbicides make it possible to seed alfalfa alone. Net return favored alfalfa establishment with oat harvested for grain and straw rather than seeding alone with herbicide in Minnesota (20). Alfalfa density in the fall of the first year was higher when seeded alone, but second year yields were not different between the two alfalfa establishment methods. In California, irrigated alfalfa was seeded alone without herbicide, or interseeded with oat planted at three rates (13). First-season alfalfa yields after the first harvest were reduced by interseeded oat, as were alfalfa and weed biomass. Alfalfa established with 18 kg ha^{-1} oat had 50% fewer weeds at the beginning of the second harvest year compared with alfalfa seeded without herbicide or oat.

Herbicides were used on only 14% of the oat, barley, and rye (*Secale cereale* L.) acreage in Nebraska in 1987; 2,4-D [(2,4-dichlorophenoxy)acetic acid] was used most frequently (3). Herbicides registered for use on oat do not adequately control grass weeds. Previous research in Nebraska (15) demonstrated the efficacy and potential selectivity of several herbicides in monoculture oat with phytotoxicity to grass weeds. PRE alachlor [2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide], metolachlor, and pendimethalin were among those applied to oat. Prodiamine had been evaluated for use in alfalfa or oat-alfalfa establishment[4].

One improvement in cultural practices would be to extend herbicide technology to oat underseeded with alfalfa to reduce weed competition. Bromoxynil is registered for POST application on oat underseeded with alfalfa but only broadleaf weeds are controlled. Several alfalfa establishment studies included application of herbicides on oat underseeded with alfalfa (4, 6, 7). Sethoxydim {2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} and imazethapyr {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid} provided grass weed control but they reduced oat growth. Sethoxydim reduced oat in oat-alfalfa forage by 37% (6) or provided 60% control of oat (4). Imazethapyr without surfactant did not injure oat but with surfactant, oat composition of the forage mix was reduced from 90% to 60% (7).

The objective of this research was to evaluate the benefits of a herbicide systems approach in a two-year rotation of spring oat underseeded with alfalfa followed by no-till corn. Specific objectives were: 1) to evaluate herbicide selectivity and impact on seeding-year yields of oat and alfalfa; and 2) carryover weed control benefits from increased legume-fixed N for second-year no-till corn.

MATERIALS AND METHODS

General. Dryland field experiments were conducted from 1985 through 1989 at the Northeast Research and Extension Center at Concord, NE. Soil types were a Maskell loam (fine-loamy, mixed, mesic Cumulic Haplustolls) in 1985 and 1988 to 1989, and an Alcester silt loam (fine-silty, mixed, mesic Cumulic Haplustolls) in 1986 to 1988. The experimental design for all studies was a randomized complete block with three to five replications. All herbicides were applied in 207 to 224 L ha^{-1} carrier with a tractor-mounted compressed-air sprayer using 11002 nozzle tips at 193 to 262 kPa pressure. Herbicide rates were expressed as kg ai ha^{-1}. All grain yields were calculated as kg ha^{-1} at 13% or 15.5% moisture for small grains and corn, respectively, and alfalfa at 1000 kg ha^{-1} at 12% moisture.

1985. A seedbed was prepared by disking and harrowing corn residue. 'Bates' and 'Perry' alfalfa were planted April 11 in 18 cm parallel drill rows at 78 and 13 kg ha^{-1}, respectively. Seeding depth was 0.6 cm for oat and 0.2 cm for alfalfa. Plot size was 4.6 by 12.2 m with three replications. PRE metolachlor, pendimethalin, and prodiamine were applied on April 11, followed by POST 2,4-DB on May 17. POST bromoxynil, tribenuron, thifensulfuron, and pyridate were also applied after PRE prodiamine. Velvetleaf (*Abutilon theophrasti* Medicus), pigweed (*Amaranthus* sp.), and green foxtail were the primary weed species. Alfalfa seedlings were counted in three 0.34 m^2 quadrats per plot May 28. Oat grain was combined on July 24. Alfalfa yields were not determined because of insufficient growth after oat harvest.

1987 to 1988. A seedbed was prepared by disking and harrowing corn residue. 'Ogle' oat and Wrangler alfalfa were seeded on April 10 in 20-cm parallel drill rows at 78 and 13 kg ha^{-1}, respectively. Seeding depths for oat

[4]Fenderson, John. 1985. Personal communication. Sandoz Crop Protection Corp., Kiowa, KS 67070.

and alfalfa were 0.6 and 0.2 cm, respectively. Because of limited seed supply, all Nitro alfalfa was surface seeded at 13 kg ha^{-1} after oat planting or herbicide application with a lawn grass seed spreader and cultipacked. Spring treatments were: 1) Wrangler alfalfa-oat seeded without herbicide or 2) with herbicide; 3) Nitro alfalfa-oat seeded without herbicide or 4) with herbicide; 5) Nitro alfalfa alone; 6) Nitro alfalfa alone with the intention to harvest one more time than in treatment 5; 7) oat alone; and 8) corn. PPI benefin at 1.2 kg ha^{-1} was applied April 10 before seeding Nitro. PRE prodiamine at 0.6 kg ha^{-1} was applied on April 10 on oat seeded with Nitro and Wrangler alfalfa. POST bromoxynil at 0.6 kg ha^{-1} was applied on May 14 to these plots. N at 67 kg ha^{-1} was broadcast over the entire area in early May.

Oat grain was combined on July 21. Alfalfa plants were counted in three 0.34 m^2 quadrats per plot on August 7 and 8. Alfalfa yields were determined at bud to first flower for as many cuttings as possible.

In November, soil cores were taken 1.5 m deep and were divided into six equal segments and analyzed for percent N by the cadmium reduction technique (16). Total N in kg ha^{-1} was calculated for the top 1.5 m of soil. Cores were taken from plots planted to oat, establishing a soil residual N base line for the other treatments planted to alfalfa. Spring-planted corn was used to bioassay for any additional legume-fixed N added to the existing residual N base. A similar soil sampling procedure was followed in all other experiments.

Alfalfa was sprayed the next spring on April 19, 1988 with 2,4-D plus dicamba (3,6-dichloro-2-methoxybenzoic acid) plus glyphosate [*N*-(phosphonomethyl)glycine] at 1.1 plus 0.3 plus 0.6 kg ha^{-1} plus a nonionic surfactant[5] at 0.25% (v/v). Glyphosate was included to kill downy brome (*Bromus tectorum* L. # BROTE) which was present where alfalfa density was low. 'Pioneer 3475' corn was planted on May 13 at 41 000 seed ha^{-1}. Starter N and P fertilizer at 10 and 15 kg ha^{-1}, respectively, were applied with the planter. Tridiphane [2-(3,5-dichlorophenyl)-2-(2,2,2-trichloroethyl)oxirane] plus cyanazine {2-[[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl]amino]-2-methylpropanenitrile} plus atrazine [6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine] at 0.6 plus 0.9 plus 0.9 kg ha^{-1} were applied POST on May 26. Corn was cultivated once. The first leaf below the corn ear shoot was collected from 10 plants per plot at corn silking. Samples were analyzed for percent N using the Kjeldahl procedure (2). Corn yield was determined by hand harvest on September 24.

1988 to 1989. A seedbed was prepared in corn stubble by disking and plots measuring 4.6 by 7.6 m were established with four replications. 'Hazel' oat and Wrangler and Nitro alfalfa were planted April 12 at 78, 13, and 13 kg ha^{-1}, respectively, in 20 cm parallel drill rows. Seeding depths for oat and alfalfa were 0.6 cm and 0.2 cm, respectively. Treatments were: 1) oat-Wrangler alfalfa seeded without herbicide or 2) with herbicide; 3) Wrangler alfalfa alone; 4) oat-Nitro alfalfa seeded without herbicide or 5) with herbicide; 6) Nitro alfalfa alone; 7) Nitro alfalfa alone for one additional cutting compared to treatment 6; 8) oat alone; 9) and 10) corn. PPI benefin at 1.2 kg ha^{-1} and PRE pendimethalin at 1.4 kg ha^{-1} were applied on April 14, respectively, to alfalfa seeded alone or oat-alfalfa seeded together. POST bromoxynil at 0.3 kg ha^{-1} was applied to all plots previously treated with herbicide.

Pioneer 3475 corn was planted on May 13 at 41 000 seed ha^{-1} in appropriate plots. Metolachlor plus cyanazine at 2.2 plus 2.2 kg ha^{-1} were applied on May 13 and N at 56 kg ha^{-1} was broadcast only on corn. Alfalfa was harvested three or four times during the season from plots where alfalfa had been planted alone. Alfalfa density was determined by counting plants in three 0.34 m^2 quadrats per plot. Oat grain was combined July 25. Soil cores were taken 1.5 m deep for residual N in monoculture oat plots as described previously.

In 1989, corn stalks from 1988 were shredded. One set of plots with corn residue was treated with cyanazine plus atrazine plus 2,4-D at 2.9 plus 1.0 plus 0.6 kg ha^{-1}, respectively, plus 2.3 L ha^{-1} of 83% paraffin base oil applied early preplant on April 20. The other set of corn plots was disked on April 20, PRE cyanazine plus atrazine were applied at 2.9 plus 1.0 kg ha^{-1}, and plots were field cultivated twice. Alfalfa was sprayed with 2,4-D plus dicamba at 1.1 plus 0.3 kg ha^{-1} on April 20, followed by early preplant cyanazine plus atrazine at 2.9 plus 1.0 kg ha^{-1} on April 21. Glyphosate at 0.6 kg ha^{-1} plus X-77 at 0.5% (v/v) plus $(NH_4)_2SO_4$ at 2% (w/v) were applied in 124 L ha^{-1} for downy brome control in plots which had been planted to oat in 1988. 'Pioneer 3379' corn was planted on May 12 at 41 000 seeds ha^{-1} without fertilization. The plot area was cultivated once.

[5]X-77, a mixture of alkylaryl polyoxyethylene glycols, free fatty acids, and isopropanol. Valent USA Corp., P.O. Box 8025, Walnut Creek, CA 94596-8025.

Table 1. Weed control, density, and yield of alfalfa planted with oat in 1985.

Treatment[b]	Herbicide rate	Application method	Weed control[a] ABUTH	AMA spp	SETVI	Alfalfa Injury	Density	Oat Injury	Yield
	kg ha^{-1}		%			%	no. m^{-2}	%	kg ha^{-1}
Untreated	0	—	0	0	0	0	119	0	3150
Metolachlor	2.2	PRE							
+ 2,4-DB	1.1	POST	72	93	95	17	96	7	3300
Pendimethalin	1.1	PRE							
+ 2,4-DB	1.1	POST	83	95	95	20	98	17	2940
Prodiamine	0.6	PRE	30	83	85	3	105	3	2900
Prodiamine	0.6	PRE							
+ 2,4-DB	1.1	POST	73	93	95	20	96	7	3150
Prodiamine	0.6	PRE							
+ bromoxynil	0.3	POST	67	95	93	23	83	7	2800
Prodiamine	0.6	PRE							
+ tribenuron	0.018	POST							
+ X-77	0.25% v/v	POST	93	95	93	93	34	73	2150
Prodiamine	0.6	PRE							
+ thifensulfuron	0.035	POST							
+ X-77	0.25% v/v	POST	90	96	95	47	75	3	3080
Prodiamine	0.6	PRE							
+ pyridate	1	POST	20	93	93	3	98	27	2220
LSD (0.05)			25	17	10	13	49	12	465

[a]ABUTH = velvetleaf; AMA spp = pigweed species; SETVI = green foxtail.

[b]X-77 = nonionic surfactant.

The first leaf below the corn ear shoot was collected from 10 plants per plot at corn silking for percent N determination as described previously. Corn was combine harvested October 12.

Data for each experiment were subjected to an analysis of variance and treatment means were compared with an LSD test (P = 0.05).

RESULTS AND DISCUSSION

Herbicide selectivity for oat-alfalfa. In 1985 alfalfa or oat injury was 3% from PRE-applied prodiamine alone at 0.6 kg ha^{-1} (Table 1). PRE prodiamine, metolachlor, and pendimethalin plus POST 2,4-DB broadened the weed control spectrum, while visual alfalfa injury was 17 to 20% and oat injury was 7 to 17% (Table 1). Oat yield with these herbicides was not different than the untreated control (Table 1), similar to previous reports (15). Velvetleaf, pigweed, and green foxtail density in untreated plots was 4, 4, and 8 plants per m^2, respectively. Prodiamine plus pyridate injured oat 27% and controlled 20% of velvetleaf, resulting in lower oat yield. Oat plants have marginal tolerance to pyridate[6].

[6]Figuerola, Luis. 1992. Personal communication. Agrolinz, Inc., Memphis, TN 38120-1303.

PRE prodiamine did not greatly injure alfalfa and assuming that there were no interactions between PRE prodiamine and later POST treatments, POST tribenuron severely injured both oat and alfalfa (Table 1). Alfalfa showed marginal tolerance to POST thifensulfuron; 47% alfalfa injury was recorded and seedling density was lower.

PRE prodiamine plus POST bromoxynil were applied on oat-alfalfa in 1987. Prodiamine was not effective on green foxtail even though 3 cm of rain came within 10 d after herbicide application (Table 2). Weed control with PRE prodiamine can be erratic because of its low water solubility and strong adsorption to soil (26). Bromoxynil controlled nearly 100% of velvetleaf and 1987 oat yield was increased compared with untreated oat-alfalfa (Table 2). In alfalfa alone, PPI benefin provided 400% better green foxtail control compared with prodiamine applied on oat-alfalfa.

PRE pendimethalin controlled 65% of green foxtail compared to 20% in untreated oat-alfalfa in 1988 (Table 3). Velvetleaf and green foxtail density in untreated plots was 4 and 50 plants per m^2, respectively. Heavy weed pressure and marginal rainfall were responsible for the fair grass control rating. Pendimethalin did not injure alfalfa seedlings (Table 3), but 20% injury was observed with PRE pendimethalin plus POST 2,4-DB in 1985 (Table 1). Proost and Buhler (19) reported that

Table 2. Weed control and alfalfa density and yield during 1987 alfalfa establishment alone or with oat, and 1988 no-till corn yield in killed alfalfa.

Treatment	1987						1988 Corn	
	Weed density[a]			Oat yield	Alfalfa		Leaf N at silking	Yield
	ABUTH	AMA spp	SETVI		Density	Yield		
	no. m^{-2}			kg ha^{-1}	no. m^{-2}	1000 kg ha^{-1}	%	kg ha^{-1}
Alfalfa[b] + oat no herbicide	35	4	18	2110	84	1.6[c]	2.04	1130
Alfalfa[b] + oat with herbicide[d]	1	5	21	2800	88	1.9[c]	1.98	1070
Alfalfa[e] + oat no herbicide	18	1	21	2090	136	3.8[f]	1.93	880
Alfalfa[e] + oat with herbicide[d]	0	1	19	2820	138	3.7[f]	2.04	1380
Alfalfa alone[e,g]	0	0	7	—	144	9.9[h]	1.98	880
Alfalfa alone[e,g]	4	0	3	—	141	12.7[i]	2.05	310
Oat	1	0	28	2720	—	—	1.98	3390
Corn, disked planted	—	—	—	—	—	—	2.03	2010
LSD (0.05)	16	5	11	440	31	0.9	NS	880

[a]ABUTH = velvetleaf; AMA spp = pigweed species; SETVI = green foxtail.

[b]Perennial Wrangler.

[c]One cutting on Sept. 4.

[d]PRE prodiamine + POST bromoxynil at 0.6 plus 0.6 kg ha^{-1}.

[e]Annual Nitro.

[f]Two cuttings on Sept. 4 and Oct. 5.

[g]PPI benefin + POST bromoxynil at 1.2 plus 0.6 kg ha^{-1}.

[h]Three cuttings on June 24, July 27, and Sept. 1.

[i]Four cuttings on June 24, July 27, Sept. 1, and Oct. 5.

PRE pendimethalin injured alfalfa and reduced yields. They suggested PRE pendimethalin would not control weeds satisfactorily without a high risk of alfalfa injury. PPI benefin gave 88% green foxtail control in alfalfa alone treatments (Table 3).

Pendimethalin and metolachlor are effective herbicides which could control grass weeds, and when followed with POST bromoxynil or 2,4-DB, provide broad spectrum weed control in oat-alfalfa with minimal injury. Such treatments increased oat yield in only one of three years (Tables 1, 2, 3).

Alfalfa yield response to herbicides. Alfalfa density and yield in 1987 and 1988 were not different for paired treatments of Wrangler or Nitro alfalfa-oat with or without herbicides (Tables 2 and 3). Nitro alfalfa seeded alone with herbicides and harvested three or four times yielded 264 and 339% more alfalfa in 1987, respectively, than did Nitro seeded with oat (Table 2). Similar results were found in 1988 when Nitro seeded with oat produced zero yield but when seeded alone, up to 8700 kg ha^{-1} forage was harvested (Table 3). For maximum forage and legume-fixed N production, Nitro alfalfa requires a specific harvest management, and absence of competition from weeds and small grains (10, 23).

Nondormant Nitro alfalfa seeded with oat yielded 214% more forage when cut on September 4 and October 5 than did Wrangler seeded with oat and cut once on September 4 (Table 2). Nitro continued fall growth longer than did Wrangler, permitting a second cutting. In Minnesota, total seeding-year forage yield of Nitro alfalfa was not different than that of the dormant cultivar Saranac (10, 23). In the present research, first cutting forage yield of Nitro and Wrangler alfalfa on September 4 were not different at 1700 kg ha^{-1}, indicating that greater density of Nitro compared to Wrangler (137 vs. 86 plants per m^2) was not a contributing factor in higher Nitro alfalfa yield (Table 2).

Corn yield following one-year alfalfa. Corn yields following alfalfa varied with rainfall, soil residual N, and the level of legume-fixed N (Tables 2 and 3). Residual soil N before corn planting was 138 and 105 kg ha^{-1} in 1988 and 1989, respectively. This much residual N could diminish any dryland corn yield response from additional legume-fixed N. Only 10 kg ha^{-1} N was applied to corn as a starter fertilizer in

Table 3. Weed control and alfalfa density and yield during 1988 alfalfa establishment alone or with oat, and 1989 no-till corn yield in killed alfalfa.

	1988					1989	
						Corn	
	Weed control[a]		Oat	Alfalfa		Leaf N	
Treatment	ABUTH	SETVI	yield	Density	Yield	at silking	Yield
	%		kg ha^{-1}	no. m^{-2}	1000 kg ha^{-1}	%	kg ha^{-1}
Alfalfa[b] + oat no herbicide	20	20	500	60	0[c]	2.58	2630
Alfalfa[b] + oat with herbicide[d]	82	75	460	90	0[c]	2.53	2010
Alfalfa alone[b,e]	86	87	—	162	5.9[f]	2.57	1190
Alfalfa[g] + oat no herbicide	20	20	500	78	0[c]	2.54	1380
Alfalfa[g] + oat with herbicide[d]	88	55	460	69	0[c]	2.59	1000
Alfalfa alone[e,g]	86	89	—	150	5.9[f]	2.46	2130
Alfalfa alone[e,g]	85	88	—	165	8.7[h]	2.45	1070
Oat	20	20	500	—	—	2.42	1690
Corn, disked planted	—	—	—	—	—	2.52	4010
Corn, no-till	—	—	—	—	—	2.55	5140
LSD (0.05)	8	10	NS	30	1.5	NS	1380

[a]ABUTH = velvetleaf and SETVI = green foxtail.

[b]Perennial Wrangler.

[c]Drought and oat competition prohibited forage harvest.

[d]PRE pendimethalin + POST bromoxynil at 1.4 plus 0.3 kg ha^{-1}.

[e]PPI benefin + POST bromoxynil at 1.2 plus 0.3 kg ha^{-1}.

[f]Three cuttings on June 22, July 28, and Sept. 13.

[g]Annual Nitro.

[h]Four cuttings on June 22, July 28, Sept. 13, and Oct. 20.

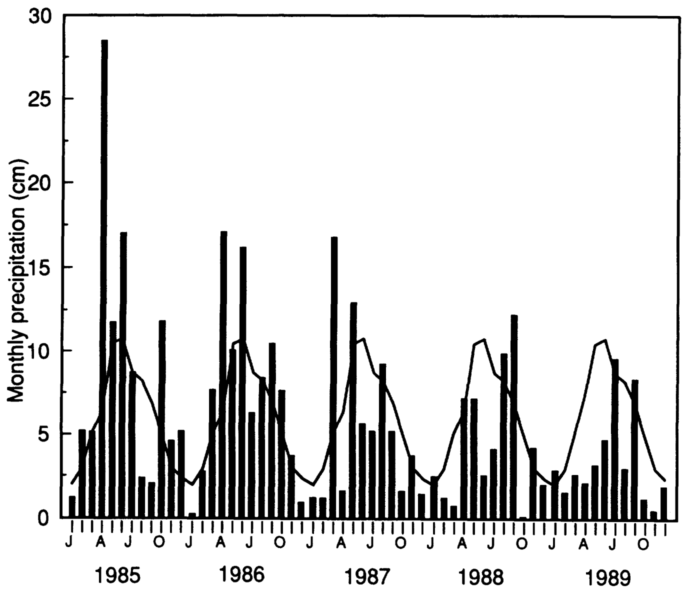

Figure 1. Monthly precipitation (bars) from 1985 to 1989 and 30 yr average monthly precipitation (line) for National Weather Station, near Northeast Research and Extension Center, Concord, NE.

1988, and no N was applied in 1989. Corn ear-leaf N concentration was in the low range of sufficiency (21), but treatment differences were not significant (Tables 2 and 3). Corn yields in 1988 and 1989 were lower following alfalfa than after corn and oat, probably due to soil moisture depletion by alfalfa (Tables 2 and 3). Precipitation for 1988 and 1989 was below normal (Figure 1), which negated any positive response to legume-fixed N addition to the soil.

Second-year dryland corn yields were not reduced following first-year alfalfa in Minnesota, but annual precipitation was near or above normal (9). Full season or winter legumes may deplete soil moisture reserves and limit subsequent crop yields in some years, especially drought years (1).

Harvest of alfalfa in 1987 and 1988 continued in the various cutting schedules from September 15 to October 5, resulting in minimal regrowth before killing temperatures occurred. This may have limited the contribution of legume-fixed N to the following corn. Heichel (9) developed N budgets for seeding-year alfalfa and showed that different herbage removal schedules affected fixed-N return to the soil. If the management scheme did not return much N-rich herbage to the soil after plowing, there may be little change in soil N. In the present research, alfalfa was killed by herbicides rather than plowing. Even though tillage may increase N mineralization, corn yield following alfalfa was not different with conventional or no-tillage (14). More rapid decomposition of hairy vetch (*Vicia villosa* Roth) residue was reported with disking or plowing compared to no-till (18, 25).

Higher corn yield following oat in 1988 may be due to the rotation effect (Table 2). Changing the sequence of crops benefits subsequent grain yields without the necessity of including a legume that can fix N (8). In 1989, corn following corn produced the highest yield (Table 3). Corn yield following oat was lower than expected, probably due to excessive weed growth in oat and stubble. Foxtail regrowth in oat stubble was shredded twice but foxtails probably continued to deplete soil moisture reserves through the summer.

In summary, these studies demonstrated that spring oat underseeded with alfalfa has good tolerance to PRE metolachlor, pendimethalin, and prodiamine for grass weed control, and to POST bromoxynil or 2,4-DB for broadleaf control. Oat yield was increased only one of three years, and alfalfa yields were not different between paired treatments of Wrangler and Nitro alfalfa-oat with or without herbicides. Drought during the experimental years limited oat and alfalfa yield response to herbicides. As a result of drought, second-year corn yield following one-year alfalfa was lower than when corn followed monoculture oat or corn. With these environmental conditions, we were unable to show benefits from a herbicide systems approach in a two-year rotation of spring oat underseeded with alfalfa followed by no-till corn.

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