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Alfalfa Yield and Quality as Influenced by Establishment Method

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ABSTRACT

Weed control during alfalfa (*Medicago sativa* L.) establishment is a primary concern of forage producers. Companion crops and clear-seeding with an herbicide are commonly used methods for establishing alfalfa. This study evaluated an alternative method in which alfalfa is seeded into a winter-killed mulch residue from a fall-seeded winter cover crop of oat (*Avena sativa* L.) and compared it with seven other establishment methods: (i) drilled with postemergence application of imazethapyr {(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-2-imidazol-2-y1]-5-ethyl-3-pyridinecarboxylic acid}, (ii) drilled with postemergence application of sethoxydim {2-[1-(ethoxyimino)butyl] 5-[2-(ethylthio)propo]-3-hydroxy-2-cyclohexen-1-one}, (iii) drilled with no oat and no herbicide, (iv) oat companion crop harvested for silage, (v) oat companion crop harvested for grain, (vi) spring-planted oat drilled with postemergence application of sethoxydim, and (vii) broadcast seeding without weed control. Field studies were conducted at two Iowa locations in 1996 and 1997. The oat companion-crop treatment harvested for silage yielded the greatest forage dry matter (DM) in the establishment year. However, drilled treatments without an oat companion crop, including the control, resulted in greater alfalfa stand densities. Treatments with sethoxydim had lower grass weed densities in the establishment year while the drilled control and oat residue mulch treatment had the greatest. Treatments containing oat, and clear-seeded with imazethapyr, had the lowest broadleaf weed densities in the establishment year. During the establishment year, forage quality was greatest where alfalfa density was high and weed density was low. Because no significant yield or quality differences were found among treatments in the year after establishment, method chosen for establishment should be based on forage needs during the establishment year.

Alfalfa has traditionally been established in the Midwest with a companion crop such as oat (Chapko et al., 1991; Simmons et al., 1995). Companion crops are advantageous to alfalfa during establishment because they suppress weed germination, growth, and competition and decrease the potential for soil erosion (Wollenhaupt et al., 1995). Companion crops can increase total dry matter (DM) production during the establishment year (Sturgul et al., 1990; Chapko et al., 1991). Companion crops can also negatively affect alfalfa during establishment by competing for light, moisture, and nutrients, which can lead to reduced yield (Hall et al., 1995) and decreased plant density (Lanini et al., 1991; Nickel et al., 1990). Appropriate harvest management of a companion crop is critical to successful establishment of perennial forages (Albrecht and Hall, 1995).

Weed management is important for decreasing competition with alfalfa and for increasing alfalfa yield and quality during the establishment year (Chapko et al., 1991; Hall et al., 1995). Weed control, during legume establishment without a companion crop, is critical to obtain a productive stand (Zollinger and Meyer, 1996). Herbicide use, when seeding alfalfa alone, reduces weed densities and allows better stands of pure alfalfa to be obtained in the seeding year (Schmid and Beherns, 1972). Competition, provided by weeds or companion crops, reduces the total season alfalfa yield compared with alfalfa seeded alone with an herbicide (Sheaffer et al., 1988). Lanini et al. (1991) found similar weed percentages in alfalfa treatments established with a companion crop or alone with an herbicide. Weed control during establishment also increased alfalfa shoot weight and leaf number (Stout et al., 1992).

Clear-seeding is a planting method that provides an alternative to using a companion crop. This method provides decreased competition from companion crops and increases in harvested alfalfa yields in the establishment year (Simmons et al., 1992). Herbicides are necessary for weed control and are advantageous for first-year yields of clear-seeded alfalfa (Sheaffer et al., 1988). Imazethapyr is a postemergence selective herbicide that was labeled for use on alfalfa in January 1995 (Dahmer, 1995). Imazethapyr gives excellent control of annual grass and broadleaf weeds. Some short-term plant stunting, however, can occur for alfalfa plants, but this does not lead to phytotoxic effects by harvest time (Zollinger and Meyer, 1996).

A method of establishing alfalfa that utilizes the attributes of both companion cropping and herbicide use was introduced in the late 1980s (Twidwell et al., 1993). Sethoxydim is a postemergence herbicide that can be used during alfalfa establishment to control grass weeds or oat (Twidwell et al., 1993). Sethoxydim application to alfalfa and oat is very effective in killing the companion crop and other grass weeds that might be present. This provides a pure stand of high quality alfalfa forage for harvest (Stute and Posner, 1993). A postemergence application of sethoxydim to oat growing with alfalfa can also optimize alfalfa yields in the establishment year (Curran et al., 1990; Twidwell et al., 1993). Another

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Abbreviations: ADF, acid detergent fiber; ADL, acid detergent lignin; CP, crude protein; DM, dry matter; IVDMD, in vitro dry matter digestibility; NDF, neutral detergent fiber.

potential establishment method, which may impart the same benefits without the use of herbicides, would be to spring-plant alfalfa into the residue of an oat crop that had been planted the previous fall for winter cover. This approach would provide excellent soil cover for erosion control during winter and at the same time eliminate the need for applying an herbicide to control competition from oat in the spring.

The objective of this study was to evaluate alfalfa establishment when planted into the residue of a winter-killed oat cover crop and compare it with several other establishment methods. The other methods evaluated were: (i) drilled with postemergence application of imazethapyr, (ii) drilled with postemergence application of sethoxydim, (iii) drilled with no oat and no herbicide, (iv) oat companion crop harvested for silage, (v) oat companion crop harvested for grain, (vi) spring-planted oat drilled with postemergence application of sethoxydim, and (vii) broadcast seeding without weed control.

MATERIALS AND METHODS

The experiment was conducted at two Iowa State University research farms: the Agronomy and Agricultural Engineering Research Farm (41°59′ N, 93°55′ W) near Ames and the Northwest Research Farm (42°96′ N, 95°33′ W) near Calumet. The soils are classified as a Nicollet loam soil (fine-loamy, mixed, mesic Aquic Hapludoll) at Ames and a Sac Galva Primghar loam soil (fine-silty, mixed, mesic Typic Hapludoll) at Calumet. At both locations, the fields used for the study were cropped with soybean [*Glycine max* (L.) Merr.] in the season before application of the treatments.

Oat for the winter-killed residue mulch treatment was established in the fall of 1995 at both locations. 'Starter' oat was drilled into a conventionally prepared seedbed at 70 kg ha^{-1} on 31 August and 5 September at Ames and Calumet, respectively. 'Alfagraze' alfalfa (inoculated) was seeded at a rate of 16.8 kg ha^{-1} pure live seed for all establishment treatments during the spring of 1996. Alfalfa was seeded with a Tye forage drill into a conventionally prepared seedbed at a depth of 5 mm with 20-cm row spacing for all treatments except the residue mulch treatment and broadcast control treatment, which were seeded with a Brillion cultipacker-type seeder. The latter treatments were seeded without additional tillage so that the oat residue remained intact. For the oat companion seeding treatments, Starter oat was seeded in 20-cm rows at 90 kg ha^{-1} pure live seed using a Tye drill at a depth of 2 cm. Alfalfa with oat treatments were seeded 11 and 19 April 1996 at Ames and Calumet, and clear-seedings of alfalfa were made 1 and 7 May 1996 at Ames and Calumet, respectively. Broadcast treatments were seeded on 2 and 19 April at Ames and Calumet, respectively. Planter type and seeding date were intentionally confounded with establishment method for practical reasons. Postemergence herbicides were applied according to label directions. Imazethapyr and sethoxydim were applied on 11 and 12 June 1996 at Calumet and Ames, respectively.

Plots were 4 by 6.1 m. A 1-m strip was harvested at a height of 8 cm from the center of each plot using a flail-type forage harvester. Harvest dates for 1996 were 12 June, 19 July, and 5 September at Ames and 11 June, 24 July, and 6 September at Calumet. Harvest dates for 1997 were 10 June and 14 July at Ames and 17 June and 25 July at Calumet. A subsample of approximately 1000 g was collected from each plot and dried at 60°C for 72 h to determine forage DM, which was used to calculate DM yield. Total DM yield, therefore, represented total herbage mass including weed species. Subsamples were ground to pass through a 1-mm screen and saved for later analyses to determine herbage quality. A separate 0.2-m^2 random sample of forage was clipped from each plot before harvest to determine botanical composition and alfalfa stage of development. Samples were hand-separated into alfalfa, oat, broadleaf weeds, and grass weeds. Alfalfa development was determined and quantified using the procedures of Kalu and Fick (1981).

Herbage quality was determined using near infrared reflectance spectroscopy (NIRS) (Windham et al., 1989). A total of 50 samples, representative of all treatment combinations (year, location, and treatment), was used as the calibration set to develop NIRS prediction equations. Coefficients of determination, standard errors for calibration, and cross validation were, respectively, 0.99, 0.20, and 0.35 for crude protein (CP); 0.99, 0.51, and 1.09 for acid detergent fiber (ADF); 0.99, 0.81, and 1.17 for neutral detergent fiber (NDF); 0.98, 0.21, and 0.39 for acid detergent lignin (ADL); and 0.99, 0.87, and 1.51 for in vitro dry matter digestibility (IVDMD). Forage NDF and ADF concentrations of calibration samples were determined using an Ankom 200 fiber analyzer (Ankom Technol. Corp., 1997). Total forage N was determined by the micro-Kjeldahl technique (Bremmer and Breitenbach, 1983), and forage CP was calculated by multiplying total forage N by 6.25. Forage digestibility was determined by the IVDMD method (Marten and Barnes, 1980).

The experimental design at each location was a randomized complete block design with four replications. Data were analyzed using a combined analysis with locations fixed and blocks within locations random (McIntosh, 1983). Harvest dates within years were analyzed using a split plot in time univariate analysis (Littell et al., 1998). The effect of year on total annual DM yield, grass weed density, and broadleaf weed density was similarly analyzed as a split plot in time. Statistical analyses of treatment and harvest comparisons were conducted using the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS Inst., 1991). Mean comparisons were made using an *F*-protected least significant difference (Steel et al., 1997). All tests of significance were made at the $P \leq 0.05$ level unless otherwise specified.

RESULTS AND DISCUSSION

Weather

Annual precipitation for 1996 was 10 cm above and equal to 40-yr mean precipitation values for Ames and Calumet, respectively. Precipitation values in 1997, through the month of August, were 7.4 and 10.9 cm below the 40-yr mean for Ames and Calumet, respectively. Annual temperatures were 0.9°C above and 5.5°C below the 40-yr mean for Ames and Calumet, respectively, for 1996 and 1.1°C and 1.5°C below the 40-yr mean for Ames and Calumet, respectively, through August 1997.

Forage Yield

The greatest total forage DM yields for the establishment year (1996) occurred with oat-for-silage, oat-for-grain, and oat residue mulch treatments (Table 1). Oat for silage and oat for grain had moderate grass weed densities compared with the oat residue mulch treatment. Although the yield for residue mulch treatment

Table 1. Total forage dry matter (DM) yield, grass weed density, and broadleaf weed density for Ames and Calumet, IA in 1996 and 1997.

	Ames			Calumet		
Establishment method	DM yield	Grass weeds	Broadleaf weeds	DM yield	Grass weeds	Broadleaf weeds
	kg ha^{-1}	stems m^{-2}	plants m^{-2}	kg ha^{-1}	stems m^{-2}	plants m^{-2}
1996						
Drilled with imazethapyr	7 231	550	58	7 180	157	62
Drilled with sethoxydim	8 673	187	180	8 555	15	152
Drilled control	9 615	709	96	8 824	375	85
Oat companion for silage	11 814	501	56	10 232	156	50
Oat companion for grain	11 684	419	54	9 328	123	46
Oat companion with sethoxydim	7 703	221	73	8 381	73	78
Oat residue mulch	10 572	692	157	9 914	560	153
Broadcast control	8 382	678	198	8 595	358	133
LSD†	1 965	323	63	1 382	354	89
1997‡						
Drilled with imazethapyr	8 789	§	§	7 822	§	§
Drilled with sethoxydim	9 364	§	§	7 569	§	§
Drilled control	7 804	§	§	7 614	§	§
Oat companion for silage	8 505	§	§	6 930	§	§
Oat companion for grain	7 955	§	§	7 636	§	§
Oat companion with sethoxydim	8 335	§	§	8 293	§	§
Oat residue mulch	7 779	§	§	7 870	§	§
Broadcast control	7 771	§	§	8 348	§	§
LSD	NS¶			NS		

† Least significant difference ($P < 0.05$).
‡ Data collected for two harvests in 1997.
§ Data not taken in 1997.
¶ NS, not significant ($P < 0.05$).

was high, the stands had substantial grass and broadleaf weed densities, which contributed to total forage yield. Yield of DM for clear-seeded alfalfa plus imazethapyr was significantly less than for all other treatments in 1996 (Table 1). Leaf yellowing and plant stunting of alfalfa was observed shortly after application of imazethapyr in 1996, which may have retarded growth and reduced total forage DM yield.

The first harvest in the establishment year consisted of the oat-for-silage treatment only on 12 June at Ames and 11 June at Calumet. Forage DM yields were 2842 and 2864 kg ha^{-1} at Ames and Calumet, respectively (Table 2). Although yields were not different between the locations, alfalfa stand density was nearly three times greater at Calumet. Rehm et al. (1998) similarly reported that stand densities were not directly related to DM yield in newly established stands of alfalfa.

The oat companion crop harvested for grain had the greatest total DM yield at the second harvest date at both locations (Table 2). The harvested yield was mostly oat grain and straw, however, which is more commonly fed as grain and used as bedding and not fed to livestock as forage. Oat grain yield and test weight were 3425 kg ha^{-1} and 15.3 kg at Ames and 2132 kg ha^{-1} and 14.3 kg at Calumet, respectively.

The oat residue mulch treatment produced the next highest yield for the second harvest at both locations (Table 2). Second-harvest yields were lowest for the imazethapyr treatment at both locations (Table 2). This was attributed to a negative impact of the chemical on alfalfa growth. However, plant development as measured by mean stage count was not affected by imazethapyr at either location compared with the drilled control treatment. Yield of the sethoxydim-treated plots did not differ significantly from the drilled control at the second harvest for either location. No negative effects of sethoxydim on alfalfa growth were observed.

Alfalfa stand densities at the second harvest were lowest for the oat companion and oat residue mulch treatments (Table 2). Greatest alfalfa stand densities were observed for the herbicide treatments followed by the drilled control. Simmons et al. (1995) and Lanini et al. (1991) similarly observed negative competitive effects of oat companion crops on alfalfa growth.

Forage DM yields for the last harvest in the establishment year were more similar among treatments than for earlier harvests (Table 2). At Ames, the drilled control treatment had a significantly higher DM yield than all other treatments with the exception of the oat residue mulch treatment. At Calumet, the harvested oat companion-crop treatments yielded lower than all others. Alfalfa densities increased from the second harvest for all treatments at Ames and for treatments containing oat at Calumet. Alfalfa densities were highest for herbicide treatments at Ames and tended to be higher than most other treatments at Calumet. There were no differences in alfalfa maturity among treatments at Ames. However, at Calumet, alfalfa was less mature for the oat companion crop harvested for silage than most other treatments. Curran et al. (1993) reported a similar interaction for maturity in an alfalfa establishment study conducted in South Dakota. At one location, they observed lower maturities for alfalfa established with an oat companion crop compared with herbicide and control treatments while at another, there were no observed differences in maturity.

Total forage yields for the two harvests made in the year following establishment did not differ among treatments at either location (Table 1). This result is consistent with the results of a number of other alfalfa estab-

Table 2. Dry matter (DM) yield, grass weed density, broadleaf weed density, alfalfa density, and mean stage count (MSC) for Ames and Calumet, IA in 1996.

Establishment method	DM yield	Grass weeds	Broadleaf weeds	Alfalfa	MSC
	kg ha^{-1}	stems m^{-2}	plants m^{-2}	stems m^{-2}	
Ames					
Harvest 1					
Oat companion for silage	2842	1	0	291	0.30
Harvest 2					
Drilled with imazethapyr	3046	203	42	990	0.55
Drilled with sethoxydim	4595	5	114	875	0.51
Drilled control	4008	51	77	759	0.56
Oat companion for silage	4816	23	22	293	0.05
Oat companion for grain	8313	4	9	139	0.44
Oat companion with sethoxydim	3877	9	16	314	0.46
Oat residue mulch	5911	65	110	238	0.54
Broadcast control	4193	20	160	244	0.52
LSD†	1268	160	59	200	0.49
Harvest 3					
Drilled with imazethapyr	4185	347	16	1200	1.43
Drilled with sethoxydim	4078	182	66	1031	1.34
Drilled control	5606	658	19	825	1.21
Oat companion for silage	4156	476	34	645	1.45
Oat companion for grain	3370	414	44	526	1.28
Oat companion with sethoxydim	3826	211	57	719	1.38
Oat residue mulch	4660	627	47	363	1.52
Broadcast control	4188	658	38	334	1.23
LSD	1294	323	37	258	NS‡
Calumet					
Harvest 1					
Oat companion for silage	2864	0	4	810	0.38
Harvest 2					
Drilled with imazethapyr	3737	32	48	1644	1.10
Drilled with sethoxydim	4800	1	50	1588	1.21
Drilled control	4814	124	46	1534	1.32
Oat companion for silage	5070	3	13	649	§
Oat companion for grain	7161	0	11	611	§
Oat companion with sethoxydim	4917	1	34	865	0.75
Oat residue mulch	6428	355	120	867	1.75
Broadcast control	4772	268	100	1601	1.74
LSD	1031	282	68	366	0.39
Harvest 3					
Drilled with imazethapyr	3444	125	13	1405	0.96
Drilled with sethoxydim	3755	13	102	1434	1.18
Drilled control	4010	252	39	1144	0.96
Oat companion for silage	2298	153	32	1289	0.79
Oat companion for grain	2168	128	35	1169	0.90
Oat companion with sethoxydim	3464	71	44	1023	1.11
Oat residue mulch	3486	206	34	836	1.15
Broadcast control	3823	90	34	1346	1.20
LSD	628	120	42	309	0.26

† Least significant difference ($P < 0.05$).
‡ NS, not significant ($P < 0.05$).
§ Data missing.

lishment studies in which various companion crop and herbicide treatments were compared (Brothers et al., 1994; Curran et al., 1993; Schmid and Behrens, 1972).

Weed Densities

Grass weed densities were higher at Ames than Calumet (Table 1). However, there was no treatment × location interaction. At both locations, grass weed densities were lowest for the two treatments in which sethoxydim was applied during the establishment year (Table 1). This result is consistent with the labeled use of sethoxydim and had been reported in other studies (Hall et al., 1995; Twidwell et al., 1993). Grass weed densities were highest in the two control treatments (broadcast and drill) and the oat residue mulch treatment.

All treatments containing oat (oat for silage, oat for grain, oat residue mulch, and oat treated with sethoxydim) had broadleaf weed densities similar to that of alfalfa treated with imazethapyr. Imazethapyr has been demonstrated to provide effective control of many annual broadleaf weeds and some annual grass weeds during alfalfa establishment (Darwent et al., 1997; Zollinger and Meyer, 1996).

Weed densities were very low for the first harvest, which consisted only of the oat-for-silage treatment (Table 2). At the second harvest, grass and broadleaf weed densities increased at both locations for most treatments. At Ames, there were no differences in grass weed density among treatments, with the exception of the imazethapyr treatment, which had the highest grass weed density. This likely occurred as the result of a decrease in alfalfa competitiveness caused by the adverse effect of the herbicide on alfalfa growth. Broadleaf

Table 3. Crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), acid detergent lignin (ADL), and in vitro dry matter digestibility (IVDMD) for Ames and Calumet, IA in 1996.

Establishment method	CP	ADF	NDF	ADL	IVDMD
	g kg^{-1} DM†				
Ames					
Harvest 1					
Oat companion for silage	217	241	424	19	801
Harvest 2					
Drilled with imazethapyr	186	230	359	50	715
Drilled with sethoxydim	171	252	383	55	701
Drilled control	164	266	435	40	706
Oat companion for silage	118	364	592	42	558
Oat companion for grain	78	382	608	52	504
Oat companion with sethoxydim	111	354	581	41	527
Oat residue mulch	143	299	467	48	670
Broadcast control	121	270	438	39	700
LSD‡	22	25	36	11	26
Harvest 3					
Drilled with imazethapyr	194	303	443	68	680
Drilled with sethoxydim	180	306	441	69	683
Drilled control	110	369	585	51	592
Oat companion for silage	134	339	534	53	631
Oat companion for grain	174	294	454	51	675
Oat companion with sethoxydim	178	306	451	62	683
Oat residue mulch	114	345	567	53	604
Broadcast control	120	350	557	49	627
LSD	25	24	38	11	28
Calumet					
Harvest 1					
Oat companion for silage	209	227	414	14	773
Harvest 2					
Drilled with imazethapyr	147	229	338	61	723
Drilled with sethoxydim	136	280	385	69	695
Drilled control	129	264	383	59	708
Oat companion for silage	104	365	575	58	539
Oat companion for grain	82	400	639	68	461
Oat companion with sethoxydim	122	247	425	28	614
Oat residue mulch	106	308	448	62	669
Broadcast control	119	283	398	71	700
LSD	13	44	54	16	52
Harvest 3					
Drilled with imazethapyr	178	341	481	87	622
Drilled with sethoxydim	168	328	467	80	651
Drilled control	123	346	544	63	599
Oat companion for silage	192	286	446	59	679
Oat companion for grain	206	286	425	67	682
Oat companion with sethoxydim	163	326	482	74	642
Oat residue mulch	145	335	517	63	623
Broadcast control	149	344	516	66	610
LSD	38	27	53	11	38

† DM, dry matter.
‡ Least significant difference ($P < 0.05$).

weed densities at the second harvest in Ames were lowest for the oat companion-crop treatments. Neither herbicide treatment differed from the drilled control treatment. At Calumet, the oat mulch residue and broadcast control treatments had higher grass weed densities than the other treatments, except the drilled control, which had an intermediate value. Broadleaf weed densities followed a similar trend although the drilled control did not differ from either herbicide treatment.

Grass weeds increased dramatically between the second and third harvests at Ames and to a much lesser extent at Calumet (Table 2). At both locations, the two sethoxydim treatments had the lowest grass weed densities. However, the difference was not statistically significant at Calumet because of the relatively lower grass weed pressure. Broadleaf weed densities decreased between the second and third harvest for most treatments at both locations. There were few differences in broadleaf weeds among treatments at the third harvest. However, at both locations, broadleaf weed densities of the sethoxydim-treated plots were significantly greater than the drilled control.

Forage Quality

Forage quality varied during the establishment year with treatments, location, and harvest (Table 3). There was a significant interaction between treatment and harvest for most forage quality parameters that was primarily related to the presence of either oat or weeds in the harvested forage. Forage quality was very high for the first harvest in the establishment year, with CP values >200 g kg^{-1} DM and IVDMD values >770 g kg^{-1} for both locations. At the second harvest, treatments with an oat companion crop had lower forage quality than other treatments except the broadcast control. Oat com-

Table 4. Crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), acid detergent lignin (ADL), and in vitro dry matter digestibility (IVDMD) for 1997.†

Establishment method	CP	ADF	NDF	ADL	IVDMD
	g kg^{-1} DM‡				
Drilled with imazethapyr	180	287	399	70	700
Drilled with sethoxydim	182	282	397	69	703
Drilled control	177	287	406	69	699
Oat companion for silage	181	287	406	70	695
Oat companion for grain	179	289	403	70	697
Oat companion with sethoxydim	178	290	407	70	698
Oat residue mulch	176	295	418	69	693
Broadcast control	184	288	405	70	704
LSD§	NS¶	NS	NS	NS	NS

† Data reflect Ames and Calumet combined and Harvest 1 and 2 combined.
‡ DM, dry matter.
§ Least significant difference ($P < 0.05$).
¶ Not significant ($P < 0.05$).

panion treatments had lower CP and IVDMD and higher ADF, NDF, and ADL than other treatments. This occurred because mature oat, which has relatively low quality compared with alfalfa, comprised most of the DM yield (Becker et al., 1998). Competition from oat plants reduced weed densities but also alfalfa density, which contributed to lower forage quality. At Ames, neither herbicide treatment differed from the drilled control for CP and IVDMD, yet both had a lower NDF concentration than the control. At Calumet, the imazethapyr treatment had slightly higher CP than the drilled control but did not differ for any other constituent.

In contrast to the second harvest, the oat companion-crop treatments harvested for grain and silage had higher forage quality than the other drilled treatments for the third harvest in the establishment year at Calumet (Table 3). Concentrations of ADF, NDF, and ADL were lower and CP higher for the oat companion treatments. However, there were no differences in IVDMD. The drilled control had very low quality for the third harvest in the establishment year at both Calumet and Ames, reflecting the high grass weed density that was present for this treatment (Table 2). At Ames, the herbicide treatments had higher forage quality than all other treatments except for the oat companion crop harvested for grain. Crude protein of the drilled herbicide treatments was 70% greater than the drilled control, and IVDMD was 90 g kg^{-1} greater. Becker et al. (1998) also reported superior quality for newly established alfalfa where herbicides had been used for establishment.

No differences in forage quality were observed in the year following establishment (Table 4). Brothers et al. (1994) also reported no observed differences in forage quality in the year after establishment where alfalfa was seeded with and without use of herbicides.

CONCLUSIONS

Establishment methods for alfalfa that included oat as a companion crop suppressed broadleaf weed growth more than the other treatments, including the herbicide treatments. Imazethapyr suppressed broadleaf weed growth but reduced alfalfa growth and total forage yield. Sethoxydim suppressed both grass weed and oat growth and had no negative impact on alfalfa growth. The economics of using herbicides during alfalfa establishment has been questioned (Hall et al., 1995). Herbicides do not need to be used during alfalfa establishment when little weed pressure is present (Sheaffer et al., 1988; Brothers et al., 1994). However, use of herbicides may be justified where significant weed pressure is present (Brothers et al., 1994).

Alfalfa seeded with oat in late spring (oat for silage) produced the greatest forage yield during the establishment year. However, the quality of the forage produced by oat companion treatments was lower, particularly at the second harvest date. Inclusion of oat as a companion crop for alfalfa establishment reduced broadleaf weed densities to a similar extent as imazethapyr application. Establishment without an oat companion crop or herbicide produced competitive yields during the seeding year but produced a lower quality forage due to higher weed densities. The oat residue mulch treatment did not suppress weed densities as well as the oat companion and herbicide treatments. However, this treatment may still be beneficial for providing winter cover on sites with high erosion potential. No significant differences were found for forage yield or forage quality among establishment methods during the year after establishment. Therefore, the establishment method used should be based on site-specific characteristics such as weed populations and soil erosion potential as well as the individual producer's forage needs during the establishment year.

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