

COLORADO FORAGE RESEARCH 1999

Alfalfa, Irrigated Pastures, and Mountain Meadows

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Cover Photos: (Top to bottom)

Irrigated pasture grasses and legumes being evaluated near Meeker, Colorado (See page 81 for article, Photo by Calvin Pearson).

Interseeding a mountain meadow with alfalfa using a John Deere Powr-till drill near Westcliff, Colorado (Photo by Joe Brummer).

Birdsfoot trefoil, a non-bloating legume, that was interseeded into a mountain meadow near Gunnison, Colorado (See page 101 for article, Photo by Joe Brummer).

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PREFACE

Production of forages occurs throughout the state of Colorado. In terms of value, hay in Colorado generally ranks as one of the top three agricultural commodities. The combination of all hay (alfalfa plus other) was the state's leading crop in 1998 with a total value of production estimated at \$440.49 million (Colorado Agricultural Statistics, 1999). This represented nearly 33% of the total value from all crops. Alfalfa was valued at \$318.1 million, representing 72% of the total hay value. All other hay was valued at \$122.4 million. Because of the importance of hay and forage in Colorado, this bulletin has been compiled to bring together in one publication current research being conducted on forages in the state. Although the impact, in terms of dollars invested and dollars returned from production oriented, forage related research, is difficult to calculate, there are numerous scientists and extension agents throughout the state that are conducting research and demonstration trials on the various aspects of forages in Colorado. We hope you will find this bulletin useful and we welcome any comments you may have about it.



ALFALFA VARIETY PERFORMANCE AND EVALUATION OF ADVANCED ALFALFA BREEDING LINES AT FRUITA, COLORADO 1999

Dr. Calvin H. Pearson

SUMMARY AND RECOMMENDATIONS

Many new alfalfa varieties are released by private companies each year in the U.S. Testing of all new alfalfa varieties is not possible. A variety performance test is conducted at the Fruita Research Center in which some new alfalfa varieties are evaluated during a three-year testing period. The performance of these varieties are evaluated under local conditions, thus, the findings from this test have relevance to similar growing conditions in western Colorado. This is a progress report for an ongoing study. Forage yields in the first, second, third, and fourth cuttings in the alfalfa variety performance test at Fruita in 1999, averaged across all twenty varieties, was 2.62, 2.44, 1.99, and 1.31 tons/acre, respectively. Total 1999 forage yield in the alfalfa variety performance test averaged 8.36 tons/acre. Forage yields in the first, second, third, and fourth cuttings in the advanced alfalfa breeding line evaluation, averaged across all twenty-five varieties, was 2.26, 1.91, 1.32, and 0.72 tons/acre, respectively. Total forage yield of the advanced breeding lines averaged 6.21 tons/acre in 1999.

INTRODUCTION AND OBJECTIVES

Alfalfa is produced on more acres in western Colorado than any other single crop. Evaluating varieties under western Colorado conditions provides local information to assist growers when selecting varieties for their farm. Local variety performance information is also of value to breeding and seed companies in knowing how to develop and market seed of their varieties. During 1999, we conducted two alfalfa performance tests. The cultivar performance test is conducted for a three-year testing period. Prior to planting the test plots, alfalfa breeding and seed companies are solicited for entries to enter into the test. These companies determine which of their varieties to include in the test. They pay a fee to the University for each entry. Usually, one or more public, check varieties are selected by research center personnel to include in the test.

MATERIALS AND METHODS

Alfalfa Variety Performance Test

This study was conducted at the Colorado State University Western Colorado Research Center at Fruita. The experiment is a randomized complete block with four replications. The soil is a Billings silty clay loam. The elevation at Fruita, Colorado is 4,510 feet. Average annual precipitation is 8.4 inches. Average frost-free days is 181 days. The last spring frost was April 17, 1999 and the first fall frost was October 17, 1999. The frost-free days in 1999 was 183 days (28°F base).

Fertilizer applied to plots in this study was 416 lbs P_2O_5 /acre and 88 lbs N/acre broadcast as 11-52-0 on August 13, 1998 and plowed down prior to planting. Planting occurred on August 27, 1998 at 13 lbs/acre. Pursuit was applied for weed control during 1999 at 1.44 oz/acre on February 24. Harvest dates for each cutting are shown in Table 1.

Advanced Alfalfa Breeding Lines

This study was conducted at the Colorado State University Western Colorado Research Center at Fruita to evaluate advanced breeding lines for a private company to provide them with data collected under field conditions. The data from this test and tests conducted elsewhere are used by the alfalfa breeder to select lines that could become released varieties for commercial production. The experiment is a randomized complete block with four replications. Plot size is 10-feet wide by 15-feet long. The soil is a Billings silty clay loam. Fertilizer applied to plots in this study was 312 lbs P_2O_5 /acre and 66 lbs N/acre broadcast as 11-52-0 on August 19, 1997 and plowed down prior to planting. Planting occurred on August 29, 1997 at the rate of 7 lbs seed/acre. Harvest dates for each cutting are shown in Table 2.

On September 19, 1997, Poast herbicide at 2 pts/acre and 1 qt/acre Butyrac plus 1 qt/acre of crop oil was applied in a tank mix using 31 gallons of water per acre at 40 psi. Pursuit was applied for weed control during 1999 at 1.44 oz/acre on February 24.

RESULTS AND DISCUSSION

Alfalfa Variety Performance Test

The 1999 results of Colorado State University's alfalfa variety performance test at Fruita are shown in Table 1. Plots were planted fall 1998 and data from 1999 are for the first year of the three-year testing period. Stands are excellent. Summer 1999 in western Colorado was quite rainy which made haymaking a challenge for most cuttings. Hay yields in the first cutting averaged across all twenty varieties was 2.62 tons/acre. There was a small amount of volunteer wheat in the first cutting. Fourteen of the twenty alfalfa varieties had high yields in the first cutting in 1999. Hay yields in the second cutting averaged 2.44 tons/acre. Fourteen of the twenty alfalfa varieties also had high yields in the second cutting. High-yielding varieties in the second cutting were not necessarily all the same varieties that had high yields in the first cutting. Hay yields in the third cutting averaged 1.99 tons/acre. Thirteen varieties had high third cutting yields. Hay yields in the fourth cutting averaged 1.31 tons/acre. Six varieties (DK 142, ZX 9453, Archer, Garst 6420, DK 140 and ZX 9451) had high fourth cutting yields. Total 1999 forage yield averaged 8.36 tons/acre. Several varieties of alfalfa were high yielding in the four cuttings with several of the same varieties producing high yields in two or more cuttings and in the 1999 total. Fourteen of the twenty varieties had high 1999 total yields; however, 'Ranger' and 'Ladak' were among the low yielding alfalfa varieties in most of the cuttings and were the two low yielding varieties for the 1999 total yield.

Advanced Alfalfa Breeding Lines

Forage yield of the advanced breeding lines during 1999 averaged across all entries was 6.21 tons/acre, somewhat higher than 6.08 tons/acre for 1998 (Table 2). Yields in the advanced alfalfa breeding lines were for the second year of production and were more than 2 tons/acre

lower than the average yield for alfalfa variety performance test. Data for this test is valuable for identifying productive lines that could eventually be named and released as commercial varieties. Data will be collected in this trial for another year to complete the three-year testing period.

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Table 1. Forage yields of 20 alfalfa varieties at the Western Colorado Research Center at Fruita in 1999.¹

Variety	Brand/Source	1 st Cut May 28	2 nd Cut July 7	3 rd Cut Aug 19	4 th Cut Oct 12	1999 Total ²
		----- tons/acre ³ -----				
DK 142	DEKALB	2.76	2.61	1.92	1.46	8.74
Pinnacle	Arkansas Valley Seed Co.	2.81	2.46	2.14	1.33	8.74
WL 232HQ	Germaines	3.00	2.50	1.99	1.22	8.70
ZX 9451	ABI	2.72	2.51	2.13	1.35	8.70
Garst 6420	Garst	2.83	2.42	2.02	1.41	8.69
Millennia	IFA	2.83	2.53	1.99	1.32	8.68
ZX 9453	ABI	2.47	2.59	2.09	1.45	8.60
Archer	America's Alfalfa	2.60	2.57	1.96	1.42	8.55
Archer II	America's Alfalfa	2.61	2.46	2.10	1.34	8.51
DK 140	DEKALB	2.77	2.41	1.94	1.38	8.51
TMF Multiplier II	Mycogen	2.69	2.46	2.02	1.27	8.44
ABT 350	ABT	2.64	2.50	2.00	1.26	8.40
WL 325 HQ	Germaines	2.65	2.58	1.88	1.28	8.39
Baralfa 54	Seekamp Seed	2.51	2.44	2.14	1.31	8.39
Innovator+Z	America's Alfalfa	2.69	2.30	1.90	1.30	8.20
Reno	Novartis	2.41	2.45	2.01	1.31	8.18
TMF 421	Mycogen	2.67	2.45	1.80	1.16	8.08
DK 134	DEKALB	2.30	2.42	1.98	1.29	7.99
Ranger	public	2.31	2.09	1.87	1.18	7.45
Ladak	public	2.07	2.14	1.90	1.08	7.20
Ave.		2.62	2.44	1.99	1.31	8.36
CV (%)		11.24	5.17	6.80	5.85	4.16
LSD (0.05)		0.42	0.18	0.19	0.11	0.49

¹Trial conducted at the Western Colorado Research Center at Fruita; seeded 27 August 1998.

²Table is arranged by decreasing, 1999 total yield.

³Yields were calculated on an air-dry basis.

Table 2. Forage yields of 25 advanced alfalfa breeding lines and check varieties at the Western Colorado Research Center at Fruita in 1999.¹

Variety	Brand/Source	1 st Cut May 28	2 nd Cut July 7	3 rd Cut Aug 19	4 th Cut Oct 12	1999 Total	1998 Total	98-99 Total
----- tons/acre ² -----								
Line 1	Forage Genetics	2.26	1.96	1.39	0.75	6.36	6.34	12.71
Line 2	Forage Genetics	2.32	1.95	1.47	0.77	6.51	6.18	12.69
Line 3	Forage Genetics	2.35	1.94	1.34	0.72	6.35	6.29	12.63
Line 4	Forage Genetics	2.23	1.96	1.40	0.76	6.34	6.13	12.47
Line 5	Forage Genetics	2.27	1.92	1.40	0.66	6.26	6.20	12.46
Rushmore	Novartis Seeds	2.28	1.94	1.34	0.67	6.23	6.22	12.45
Line 6	Forage Genetics	2.33	1.91	1.31	0.74	6.30	6.15	12.45
Line 7	Forage Genetics	2.37	1.92	1.33	0.70	6.32	6.11	12.43
Line 8	Forage Genetics	2.16	1.90	1.33	0.69	6.08	6.29	12.37
Line 9	Forage Genetics	2.18	1.98	1.28	0.75	6.18	6.16	12.34
Tahoe	Novartis Seeds	2.23	1.93	1.34	0.75	6.25	6.08	12.33
Line 10	Forage Genetics	2.32	1.94	1.30	0.69	6.24	6.08	12.32
Line 11	Forage Genetics	2.23	1.89	1.31	0.78	6.21	6.11	12.31
Line 12	Forage Genetics	2.29	1.86	1.33	0.73	6.21	6.10	12.31
Line 13	Forage Genetics	2.36	1.85	1.32	0.73	6.27	6.00	12.27
Line 14	Forage Genetics	2.27	1.92	1.27	0.73	6.19	6.03	12.21
Line 15	Forage Genetics	2.22	1.90	1.30	0.72	6.13	6.05	12.18
Line 16	Forage Genetics	2.11	1.88	1.33	0.75	6.07	6.10	12.17
Line 17	Forage Genetics	2.09	1.84	1.33	0.77	6.03	6.05	12.07
Line 18	Forage Genetics	2.28	1.87	1.26	0.71	6.12	5.93	12.05
P5396	Pioneer Hi-Bred	2.45	1.93	1.21	0.62	6.22	5.83	12.04
Line 19	Forage Genetics	2.21	1.85	1.32	0.65	6.04	6.00	12.04
Line 20	Forage Genetics	2.21	1.86	1.26	0.69	6.02	5.99	12.02
Line 21	Forage Genetics	2.21	1.93	1.27	0.79	6.19	5.77	11.97
Line 22	Forage Genetics	2.21	1.92	1.32	0.71	6.16	5.76	11.91
Ave.		2.26	1.91	1.32	0.72	6.21	6.08	12.29
CV (%)		5.21	4.07	6.57	7.36	3.03	4.10	
LSD (0.05)		0.19	0.12	0.14	0.08	0.30	0.39	

¹ Trial conducted at the Western Colorado Research Center at Fruita; seeded 27 August 1998.

² Yields were calculated on an air-dry basis.

**FORAGE YIELDS OF 20 ALFALFA VARIETIES AT THE SOUTHWESTERN
COLORADO RESEARCH CENTER AT YELLOW JACKET,
COLORADO IN 1996-1999¹**

Abdel Berrada

Variety	Brand/Source	1 st Cut Jun 25	2 nd Cut Aug 2	3 rd Cut Oct 4	Total				
					1999	1998	1997	1996 ²	4-yr
					-----tons/acre ³ -----				
Blazer XL	Sharp Bros. Seed Co.	2.35	1.87	1.08	5.31	7.15	7.95	3.68	24.09
5472	Pioneer Hi-Bred	2.40	2.16	1.18	5.74	7.57	7.34	3.28	23.93
330	Union Seed Co.	2.22	1.85	1.12	5.19	7.54	7.78	3.33	23.85
Reward	Drussel Seed & Supply	2.30	2.15	1.26	5.71	7.59	7.09	3.37	23.78
5454	Pioneer Hi-Bred Int'l	2.22	2.07	1.07	5.36	7.49	7.26	3.24	23.35
Sterling	Cargill Hybrid Seeds	2.10	1.91	1.07	5.08	7.02	7.46	3.61	23.16
Rushmore	Novartis	2.14	1.86	0.98	4.98	7.44	7.48	3.17	23.08
ZX 9345	America's Alfalfa	2.11	1.90	1.10	5.11	7.09	7.35	3.48	23.03
Innovator + Z	America's Alfalfa	2.15	1.83	0.98	4.96	7.12	7.17	3.36	22.61
Archer	America's Alfalfa	2.22	1.99	1.03	5.24	7.01	7.15	3.22	22.61
Evergreen	Arkansas Valley Seed	2.03	1.83	0.91	4.77	7.00	7.16	3.53	22.46
WL 323	W-L Research, Inc.	2.07	1.77	0.81	4.65	7.04	7.57	3.20	22.45
Affinity + Z	America's Alfalfa	2.10	1.83	0.85	4.78	6.90	7.29	3.31	22.27
Vernema	Southwest Seed, Inc.	2.18	1.83	0.93	4.94	6.97	7.08	3.21	22.20
WL 325	W-L Research, Inc.	2.14	1.96	1.06	5.17	7.08	6.86	3.03	22.15
AlfaLeaf II	Cal/West Seeds	2.14	1.67	0.80	4.61	7.15	7.26	3.06	22.08
Depend + E	America's Alfalfa	2.16	1.93	0.94	5.02	6.79	6.99	3.11	21.91
DK 127	DeKalb Genetics Corp.	1.91	1.87	0.97	4.76	7.05	6.89	2.95	21.64
WL 252HQ	W-L Research, Inc.	2.05	1.75	1.02	4.81	6.84	6.90	3.08	21.62
Ranger	Arkansas Valley Seed	1.78	1.80	0.77	4.35	6.77	6.71	2.93	20.75
Average		2.14	1.87	1.00	5.03	7.13	7.24	3.26	22.65
CV%					12.22	5.56	6.20	7.00	6.51
LSD _(.05)					0.87	0.32	0.63	0.44	2.09

¹Trial conducted on the Southwestern Colorado Research Center at Yellow Jacket, CO; seeded 5/15/96.

²There were only two cuttings in 1996.

³Yields were calculated on an oven-dry basis.

Comments: Frequent rains in late July and throughout August delayed the second and third cuttings in 1999, which resulted in poor hay quality at the second cutting and low to very low yields at the third cutting. The plot area was somewhat weedy in 1999, which could also have contributed to the relatively low yields in 1999. A new alfalfa variety trial will be established at a new location in the spring of 2000.

SAN LUIS VALLEY ALFALFA TRIAL AT CENTER

Merlin A. Dillon

High-Altitude Alfalfa in Colorado

Alfalfa is the most valuable crop besides potatoes in the San Luis Valley with an acreage of 140,000 and a value of \$40 million. The San Luis Valley is a large, flat intermountain valley surrounded by snow-capped mountains. The elevation of 7,600 feet makes for a cool, short growing season. Precipitation averages only 7-9 inches per year. The average frost-free period is 88 days, from June 10 to September 6. Growers are more and more using a 3-cut system. Winter hardiness and persistence are important variety selection factors as are yield and pest resistance.

Alfalfa stands in the San Luis Valley usually last 5-7 years which means about 20- to 25,000 acres are seeded each year. About half of the acreage is sprinkler irrigated under center pivots and the remainder is flood irrigated. The average yield for the area is about 3.5 tons/acre, however, the typical center pivot yields close to 5.0 or 5.5 tons/acre.

Researcher Comments on the Variety Trial

Results from the San Luis Valley alfalfa variety trial are applicable to other high mountain areas of Colorado. Colorado's high altitude alfalfa acreage is nearly 200,000 acres.

The 1999 season was cool early and especially rainy in July and August. Grower's yields were down slightly, especially the third cutting. The third cutting was reduced because rains delayed getting the second cutting off the fields. Harvest times were about normal this year: first cutting was June 16, second cutting was July 22, and third cutting was September 24. Total yield this year averaged 5.9 tons/acre. First cutting was 2.2, second was 2.1, and third cutting was 1.6 tons/acre. These yields are slightly higher than many grower's yields, especially the third cutting. Most growers baled the first and third cuttings without rain. Rain showers began in early July and rain damage for second cutting was very common.

Highly significant differences in winter injury were noted in May 1998. These differences were not important for following yields, except two varieties with low damage yielded highest in both 1998 and 1999.

As usual, Ranger (check variety) yielded the lowest. The advantage of newer varieties is usually 0.7 tons/acre, more than enough to pay the higher seed cost.

Researcher

Merlin A. Dillon, Area Agronomy Extension Agent, has conducted alfalfa trials in the San Luis Valley for 18 years. Raised on a dryland farm in southeast Colorado (Baca County), Merlin received a B.S. in Agronomy from Panhandle State University in Goodwell, Oklahoma, and an M.S. in Agronomy from Colorado State University. Merlin worked for Kansas State University, as an irrigated farm consultant, and as an independent fertilizer applicator prior to joining the San Luis Valley Research Center in 1982. Research has included small grain variety trials (wheat, barley, and oats) as well as work on quinoa, canola, and alternate crops.

Table 1. Forage yields of 20 alfalfa varieties at the Richard Ramstetter Farm, Center, CO in 1997-99.

Variety	Brand/Source	1997	1998	1999	3-Year Total	Winter Injury Rating ²		
-----tons/acre ¹ -----								
Class	Union Seed Co.	6.5	a	5.1	6.0	17.7	a ³	1.5
Pinnacle	Arkansas Valley Seed	6.3	ab	5.0	6.2	17.5	ab	2.3
Extend	Grassland West	6.3	ab	5.2	5.9	17.2	abc	4.0
ZN 9540	ABI Alfalfa	6.1	ab	5.1	5.9	17.1	abcd	3.3
Webfoot MPR	Great Lakes Hybrids	6.2	ab	4.5	5.9	17.0	abcd	2.8
Innovator+Z	America's Alfalfa	6.1	ab	5.0	6.0	17.0	abcd	3.5
Rainier	Northrup King	6.1	ab	5.0	5.9	16.9	abcd	3.5
Depend+EV	Agripro Seeds Inc	5.9	ab	5.0	6.0	16.8	abcd	4.0
WL 325HQ	W-L Research	5.8	bc	5.1	6.1	16.8	abcd	4.3
ABI 9142	ABI Alfalfa	6.1	ab	5.1	5.7	16.7	abcd	4.0
DK 127	DeKalb Genetics	6.1	ab	4.8	5.8	16.7	abcd	2.0
AmerGraze 401+Z	America's Alfalfa	5.9	bc	5.0	5.9	16.6	abcd	3.8
Vernal	USDA WI-AES	5.9	ab	5.2	5.7	16.5	bcde	3.8
DK 122	DeKalb Genetics	6.0	ab	4.6	5.6	16.3	cde	3.3
Alfaleaf II	Plains Alfalfa Assoc.	6.0	ab	5.0	5.4	16.2	cde	3.8
ZG 9543	ABI Alfalfa	5.2	cd	5.1	6.1	16.1	cde	3.0
WL 324	W-L Research	5.3	bc	4.9	6.0	16.0	de	3.3
Affinity+Z	America's Alfalfa	5.3	bc	5.0	5.8	16.0	de	4.0
WL 252HQ	W-L Research	5.1	d	4.7	5.8	15.4	ef	2.8
Ranger	USDA NE-AES	4.9	d	4.5	5.5	14.7	f	3.5
Average		5.7		5.0	5.9	16.5		3.3
CV%		8.4		8.4	7.0	6.3		
LSD (0.10)		0.57		NS	NS	1.13		

¹ Yields calculated on an air-dry basis.

² Winter Injury Rating based on observation of plant injury and death in May 1998: 5 = Severe damage; 1 = No damage.

³ Duncan's Multiple Range Test: yields followed by the same letter are not statistically different.

Planted: August 2, 1996 at 16 lbs/acre.

Fertilizer: 104 lbs/acre phosphate plus 22 lbs/acre nitrogen broadcast.

Experiment design: randomized complete block with four replications.

Soil series: Norte gravelly sandy loam.

FORAGE YIELDS OF 28 ALFALFA VARIETIES AT THE ARKANSAS VALLEY RESEARCH CENTER IN 1998-99¹

Dr. Frank C. Schweissing

Variety	Brand/Source	1 st Cut June 2	2 nd Cut July 6	3 rd Cut Aug. 16	4 th Cut Oct. 5	1999 Total	1998 Total	2-yr Total
-----tons/acre ² -----								
WS 210*	W-L Research	2.49	1.67	1.55	1.32	7.03	5.86	12.89
WL 324	Germain's	2.54	1.57	1.27	1.14	6.52	5.74	12.26
Depend + EV	Agripro Seeds Inc.	2.39	1.67	1.40	1.17	6.63	5.60	12.23
DK 143	DeKalb Genetics Corp.	2.21	1.63	1.46	1.22	6.52	5.67	12.19
3L104*	Novartis	2.61	1.43	1.36	1.19	6.59	5.57	12.16
Cimarron 3i	Great Plains Research	2.56	1.58	1.30	1.18	6.62	5.54	12.16
Millennia	Union Seed Co.	2.47	1.57	1.35	1.25	6.64	5.48	12.12
ZX 9352*	ABI Alfalfa	2.40	1.57	1.44	1.14	6.55	5.46	12.01
631	Garst Seed Co.	2.40	1.62	1.41	1.17	6.60	5.38	11.98
Leaf Master	Union Seed Co.	2.59	1.57	1.30	1.27	6.73	5.24	11.97
ZC 9651*	ABI Alfalfa	2.33	1.62	1.25	1.19	6.39	5.56	11.95
5454	Pioneer Hi-Bred	2.36	1.59	1.32	1.22	6.49	5.43	11.92
Big Horn	Cargill Hybrid Seeds	2.46	1.58	1.30	1.14	6.48	5.41	11.89
Affinity +Z	America's Alfalfas	2.42	1.53	1.30	1.19	6.44	5.44	11.88
TMF Multi-plier II	Mycogen Seeds	2.39	1.51	1.34	1.16	6.40	5.44	11.84
Pinnacle	Arkansas Valley Seed	2.34	1.70	1.29	1.15	6.48	5.35	11.83
DK 142	DeKalb Genetics Corp.	2.34	1.54	1.32	1.27	6.47	5.34	11.81
Innovator + Z	America's Alfalfas	2.18	1.60	1.34	1.15	6.27	5.43	11.70
DK 127	DeKalb Genetics Corp.	2.26	1.59	1.28	1.16	6.29	5.24	11.53
Archer	America's Alfalfas	2.19	1.56	1.36	1.18	6.29	5.24	11.53
Haygrazer	Great Plains Research	2.25	1.49	1.34	1.16	6.24	5.29	11.53
630	Garst Seed Co.	2.21	1.58	1.28	1.12	6.19	5.34	11.53
ZC 9650*	ABI Alfalfa	2.11	1.53	1.28	1.09	6.01	5.30	11.31
WL 325HQ	Germain's	2.19	1.50	1.24	1.08	6.01	5.25	11.26
Lahontan	USDA NV-AES	2.18	1.42	1.35	1.11	6.06	5.13	11.19
6L271*	Arkansas Valley Seed	2.04	1.44	1.46	1.17	6.11	5.07	11.18
Ranger	USDA NE-AES	1.85	1.30	1.17	0.93	5.25	4.71	9.96
Vernal	USDA WI-AES	1.91	1.41	1.17	0.90	5.39	4.51	9.90
Average		2.31	1.55	1.33	1.16	6.35	5.36	11.71
CV%		7.78	5.88	5.96	4.98	4.72	4.12	3.38
LSD_(0.05)		0.25	0.13	0.11	0.08	0.42	0.31	0.56

¹ Trial conducted on the Arkansas Valley Research Center at Rocky Ford, CO; planted 8/29/97.

² Yields calculated on oven-dry basis.

*Indicates experimental entry.

Elevation 4178 feet. Average annual precipitation 11.79 inches. Average frost-free days-158.

Last spring frost-April 26 1999; First fall frost-September 29, 1999; 1999 frost-free days-156.

Fertilizer: 150 lbs P₂O₅/acre plus 31 lbs N/acre prior to planting and Nov. 30, 1998.

Soil series: Rocky Ford silty clay loam.

Herbicide: Sencor 75DF .50 + Gramoxone .31 lbs AI/Acre - Feb 16, 1999.

NORTHEASTERN COLORADO ALFALFA TRIAL RESULTS AT WIGGINS, 1999

Dr. Jerry J. Johnson

The 1999 results of Colorado State University's alfalfa variety performance trial at Wiggins are provided below. These results will be used by Colorado alfalfa producers to make better alfalfa variety decisions. Planted in its present location on 3 September 1997, two cuttings were made in 1998 and all four cuttings were made in 1999. Stands were excellent in 1999 and no major pest problems were observed. We are grateful to our cooperator, Martin Smits, for his contributions to the success of this trial.

Table 1. Forage yields of 26 alfalfa varieties at Wiggins in 1999¹.

Variety	Brand/Source	1 st Cut May 28	2 nd Cut July 1	3 rd Cut Aug 6	4 th Cut Sept 13	1999 Total	1998 Total	2-yr Total
-----tons/acre*-----								
Pioneer brand 5396	Pioneer Hi-Bred Int'l, Inc.	2.48	2.15	1.66	1.76	8.05	3.71	11.76
Legacy	Grassland West Company	2.31	2.01	1.68	1.91	7.92	3.72	11.64
AlfaLeaf II	Sharp Bros. Seed Co.	2.19	2.05	1.64	1.88	7.76	3.87	11.63
Reno	Novartis Seeds	2.28	2.13	1.71	1.87	8.00	3.58	11.58
Total + Z	America's Alfalfa	2.35	1.97	1.65	1.74	7.71	3.83	11.54
Shamrock	Sharp Bros. Seed Co.	2.39	2.08	1.69	1.76	7.92	3.61	11.53
Complete	Arrow Seed Co.	2.35	2.00	1.67	1.80	7.81	3.72	11.53
Excalibur II	Allied Seed	2.29	2.01	1.62	1.82	7.74	3.69	11.43
Magnum III	Dairyland Seed Company	2.23	2.05	1.73	1.80	7.80	3.59	11.39
Innovator+Z	America's Alfalfa	2.30	2.03	1.74	1.74	7.81	3.58	11.39
DEKALB DK142	Monsanto	2.30	2.10	1.69	1.68	7.78	3.58	11.36
TMF Multi-plier II	Mycogen Seeds	2.28	2.05	1.68	1.78	7.80	3.56	11.36
Big Horn	Cargill Hybrid Seeds	2.21	2.06	1.65	1.73	7.66	3.69	11.35
Spartan	Allied Seed	2.37	1.93	1.62	1.75	7.67	3.67	11.34
WL 325HQ	W-L Research, Inc.	2.34	2.04	1.65	1.75	7.77	3.54	11.31
Garst Seed 631	Garst Seeds	2.28	2.07	1.67	1.82	7.84	3.45	11.29
DEKALB DK127	Monsanto	2.20	1.94	1.62	1.77	7.54	3.59	11.13
Depend+EV	Agripro Seed, Inc.	2.30	2.08	1.71	1.69	7.77	3.36	11.13
Garst Seed 630	Garst Seeds	2.32	2.05	1.65	1.76	7.78	3.32	11.10
AmeriGraze 401 + Z	America's Alfalfa	2.31	1.95	1.65	1.69	7.59	3.50	11.09
Pioneer brand 5312	Pioneer Hi-Bred Int'l, Inc.	2.29	1.96	1.57	1.74	7.56	3.52	11.08
Webfoot MPR	Great Lakes Hybrids	2.08	2.04	1.73	1.60	7.44	3.55	10.99
Pinnacle	Arkansas Valley Seeds	1.85	2.01	1.57	1.76	7.18	3.80	10.98
Alpha 2001	Great Lakes Hybrids	2.25	2.04	1.72	1.76	7.77	3.17	10.94
Tahoe	Novartis Seeds	1.77	1.98	1.53	1.71	6.98	3.75	10.73
Evergreen-2	Arkansas Valley Seeds	1.63	2.03	1.56	1.66	6.87	3.63	10.50
Average		2.23	2.03	1.66	1.76	7.67	3.60	11.27
CV%		5.50	4.91	5.20	6.85	2.96	9.40	
LSD_(0.30)		0.09	0.07	0.06	0.09	0.17		
LSD_(0.05)		0.17	0.14	0.12	0.17	0.32	0.50	

¹ Trial conducted on the Martin Smits farm (NW 1/4 of Section 4, T 3N, R 60W), seeded 9/3/97.

*Yields calculated on oven-dry basis and adjusted to 14% moisture.

Elevation: 4750 ft.

Soil series: Valent loamy sand with some bijou loamy sand characteristics.

EQUIPMENT TRAFFIC DURING ALFALFA HARVEST CAN AFFECT YIELD AND QUALITY

Eric Rechel and Tim Novotny

SUMMARY AND RECOMMENDATIONS

Cultural practices used to harvest alfalfa often subject large portions of the field to tractor and equipment traffic. This traffic results from the numerous field operations that occur between swathing and bale removal. Understanding the extent these practices affect plant growth patterns will aid in quantifying their impact and may be useful in mitigating damage they cause. The objective of this study was to determine the effect of harvest traffic on alfalfa yield and plant quality. The experiment consisted of four treatments with various amounts of traffic, ranging from 0 to 89%, applied seven days after swathing. This is the third year of a four-year experiment. There was no significant difference in yield among treatments during the first two years of production. Plots with 89% trafficked area had a significant reduction in yield the third and fourth cuttings in the third year of production. Quality, as measured by relative feed value, was significantly higher in third and fourth cuttings of every year in trafficked plants. This has consequences in breeding programs where quality variables are being compared between small untrafficked research plots and a growers operation. Increased quality in the trafficked lanes in the latter harvests of all three years may have little impact on the quality determination for an entire field. Under the conditions of this experiment, traffic was not shown to significantly reduce yield until the later cuttings in the third year of production. Long-term yields may be affected when relatively large portions of the field are subjected to harvest traffic. To achieve optimal yields, growers should implement procedures that minimize the area of the field subjected to traffic.

INTRODUCTION AND OBJECTIVES

Management strategies used to optimize yield in alfalfa usually are concerned with variety selection, insect and weed control, and harvest schedules (Hanson et al., 1987). There is little scientific information on how harvest traffic may influence yield. This aspect on alfalfa production needs some definitive answers as to the impact of harvest traffic given the weight of the machinery used, the percentage of the field impacted, and the timing of the different operations during harvest.

In southern California, a major research project was conducted to quantify how tractor traffic applied to alfalfa during harvest affected soil parameters and alfalfa regrowth. This alfalfa production system used a semi-dormant variety and averaged 7 cuttings a year. These experiments studied the impact of tractor traffic on soil bulk density and water infiltration rates (Meek et al., 1988, 1989) fine root growth patterns, water use efficiency, and over all yield (Rechel et al., 1990, 1991a,b). Data on the development of leaf area and changes in leaf/stem ratios (Rechel, 1996) suggested traffic may also alter alfalfa quality.

To better understand how tractor traffic affects alfalfa growth, data are needed from a range of climates and agricultural systems. Alfalfa production in western Colorado provides a production system that can be compared to the California study. The major differences are the use of dormant varieties averaging 3.5 cuttings a year. This is the third year of a four year experiment. The objectives of this study were to 1) quantify long term yield and compare it to the studies conducted in California, and 2) determine if harvest traffic affects alfalfa quality.

MATERIALS AND METHODS

Alfalfa, variety 'WL 323', was planted August 1996 at the Colorado State University Fruita Research Center at 18 pounds per acre. The experiment will be terminated in the fall of 2000. The soil is a Youngston clay loam. The elevation is 4,510 feet with an average rainfall of 8.4 inches per year. The field consists of rows on 30 inch centers with furrows approximately 4 inches deep and 6 inches wide. Each plot is 12 feet wide (4 rows) and 20 feet long.

Alfalfa is subjected to 4 different levels of tractor traffic with 4 replications. At each harvest, all plots receive traffic from the swather. During the next 3 to 5 days, the harvested alfalfa was removed by hand from all plots. Seven days after swathing, traffic treatments were applied with a John Deere 2955 as follows:

Treatment 1 - No additional traffic applied.

Treatment 2 - One pass of the tractor over each plot with the right wheel centered over the same row as the right wheel of the swather. This represents 22% of the plot being trafficked.

Treatment 3 - All four rows in each plot were trafficked from single passes of the tractor. This represents 44% of the plot being trafficked.

Treatment 4 - All four rows and furrows were trafficked representing 89% of the plot being trafficked.

The above traffic created lanes of alfalfa in each plot subjected to different degrees of traffic. Four of these patterns were selected for further measurement and were defined as (a) NT, rows never receiving traffic, (b) S, the row receiving only swather traffic, (c) TR, rows receiving traffic seven days after swathing, and (d) STR, rows receiving traffic from the swather and traffic seven days after swathing. Forage yield and relative feed value (RFV) were determined in these four treatments by harvesting a randomly selected 2.8 ft² area in each plot. Forage yield across the entire plot was also determined.

The experimental design for the whole plot yields was a Latin square. Data for trafficked and RFV were analyzed as a randomized complete block.

RESULTS AND DISCUSSION

In the California studies, yield was a result of an interaction between the amount of traffic, year of production, and when the harvest occurred within a year (Rechel et al., 1990). When the traffic was applied in a manner to simulate grower conditions, there was no significant reduction in yield the first year (Rechel et al., 1991). In contrast, the treatment where 100% of the plot was

trafficked after each harvest, there was a significant reduction in yield the first year of production.

Our study showed no significant decrease in total yield the first two years of production among traffic treatments (Fig. 1). In the third year, only the treatment where 89% of the plot was trafficked was there a significant reduction in yield and this was evident only in the third and fourth cuttings.

Harvest traffic effects on alfalfa production may not become evident during the first several cuttings or even during the first year of production. In the California studies, it was not until the third cutting in the second year that grower-simulated traffic reduced yield. In our study, it was not until the latter cuttings in the third year, when 89% of the field was trafficked, that yield was significantly reduced.

Yield from the small plot samples, taken in the different trafficked lanes, also showed no significant difference until the third and fourth harvests in the third year of production (Table 1). At this time, the repeated traffic at the time of swathing and seven days later caused a decrease in yield. The results from the small plot yields follow the trend of the whole plot yields, i.e., traffic did not significantly affect yield until the third year of production.

In contrast to the yield data, significant differences in RFV were observed in all three years during the third and fourth harvests (Table 1). It was the trafficked STR lane of the plots that had significantly higher quality than the non-trafficked NT and S lanes of the field (Table 1). The increased RFV can usually be attributed to some form of plant stress (Buxton and Fales, 1994) which, in our experiment, was tractor traffic.

Temperature, water deficit, soil nutrient concentration, and insect pests can all cause plant stress and subsequently affect forage quality (Buxton and Fales, 1994). They review the numerous environmental factors responsible for higher quality and comment that a change in leaf/stem ratio may have the greatest influence. In the recent book, *Forage Quality, Evaluation, and Utilization* (Fahey, 1994), there was no mention, however, of tractor traffic affecting quality.

It must be remembered the increased RFV was only determined in specific trafficked lanes within a specific traffic treatment. Growers take several random samples from each lot which are then combined for quality determination. Under their commercial production system, growers may not detect differences similar to our findings. There may, however, be increased variability in quality measurements from third and fourth cuttings. This suggests more samples may be required from these cuttings to accurately ascertain quality.

This experiment examined only one variable; the portion of the field trafficked after each cutting by a specific tractor. However, to thoroughly define the response of alfalfa to harvest traffic, several additional variables should be quantified. These include the number of days after swathing the traffic is applied, the weight of the equipment, and the number of times the alfalfa is subjected to traffic at each harvest. The results presented here suggest all these may have a significant negative impact on alfalfa growth. To achieve long-term optimal yields, a grower should consider modifying the harvesting procedure to reduce the number of passes over the field at each harvest and remove the hay as expediently as possible after swathing.

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LITERATURE CITED

- Buxton, D.R., and S.L. Fales. 1994. Plant environment and quality. *In*: Fahey, G.C. (ed.), Forage quality, evaluation, and utilization. Amer. Soc. Agron., Madison WI. p.155-199.
- Fahey, G.C. 1994. Forage quality, evaluation, and utilization. Amer. Soc. Agron., Madison WI.
- Hanson, A.A., D.K. Barnes, and R.R. Hill. 1987. Alfalfa and alfalfa improvement. Agronomy #29. Amer. Soc. Agron., Madison WI.
- Meek, B.D., E.A. Rechel, L.M. Carter, and W.R. DeTar. 1988. Soil compaction and its effect on alfalfa in zone production systems. Soil Sci. Soc. Amer. J. 52:232-236.
- Meek, B.D., E.A. Rechel, L.M. Carter, and W.R. DeTar. 1989. Changes in infiltration under alfalfa as influenced by time and wheel traffic. Soil Sci. Soc. Amer. J. 53:238-241.
- Rechel, E.A., B.D. Meek, W.R. DeTar, and L.M. Carter. 1990. Fine root development of alfalfa as affected by wheel traffic. Agron. J. 82:618-622.
- Rechel, E.A., B.D. Meek, W.R. DeTar, and L.M. Carter. 1991a. Alfalfa (*Medicago sativa* L.) water use efficiency as affected by harvest traffic and soil compaction in a sandy loam soil. Irrig. Sci. 12:61-65.
- Rechel, E.A., B.D. Meek, W.R. DeTar, and L.M. Carter. 1991b. Alfalfa yield as affected by harvest traffic and soil compaction in a sandy loam soil. J. Prod. Agric. 4:241-246.
- Rechel, E.A., and T.J. Novotny. 1996. Growth analysis of alfalfa subjected to harvest traffic. Crop Sci. 36:1006-1011.

Table 1. Yields from 2.8 ft.² quadrats and relative feed value for each cutting in the different traffic lanes for three years of alfalfa production.

1997		Small plot yields	Relative Feed Value
		lbs /yd ²	
May 27	Swather	1.13	157.2
	Non-Traffic	1.17	159.2
	Swather + Traffic	1.03	159.8
	Traffic	1.00	159.0
July 3	Swather	0.79	151.6
	Non-Traffic	0.92	148.7
	Swather + Traffic	0.75	154.1
	Traffic	0.71	151.7
August 15	Swather	0.53	143.2a*
	Non-Traffic	0.55	144.0a
	Swather + Traffic	0.44	156.0b
	Traffic	0.50	151.3ab
October 1	Swather	0.40	179.3a
	Non-Traffic	0.42	172.0a
	Swather + Traffic	0.32	190.0b
	Traffic	0.37	189.1b
1998			
May 27	Swather	1.10	153.1
	Non-Traffic	1.05	148.2
	Swather + Traffic	0.87	157.4
	Traffic	0.93	155.4
July 8	Swather	0.84	136.8
	Non-Traffic	0.88	132.1
	Swather + Traffic	0.78	141.5
	Traffic	0.83	140.9
August 18	Swather	0.52	141.7ab
	Non-Traffic	0.49	138.3a
	Swather + Traffic	0.38	149.1c
	Traffic	0.40	144.6bc
October 8	Swather	0.48	188.1ab
	Non-Traffic	0.43	184.9a
	Swather + Traffic	0.36	193.9b
	Traffic	0.41	194.2b
1999			
May 28	Swather	1.02	172.6ab
	Non-Traffic	1.02	168.6a
	Swather + Traffic	0.86	181.5b
	Traffic	0.89	178.5b
July 7	Swather	0.80	140.6
	Non-Traffic	0.97	141.7
	Swather + Traffic	0.80	137.2
	Traffic	0.93	138.1
August 19	Swather	0.83a	142.4a
	Non-Traffic	0.83a	146.0a
	Swather + Traffic	0.52b	165.2b
	Traffic	0.69ab	160.1b
October 19	Swather	0.34b	222.9b
	Non-Traffic	0.45a	209.6a
	Swather + Traffic	0.27c	234.6c
	Traffic	0.34b	231.5bc

*Values within a column, within a year, within a cutting, followed by the same letter are not significantly different by LSD ($P \leq 0.05$).

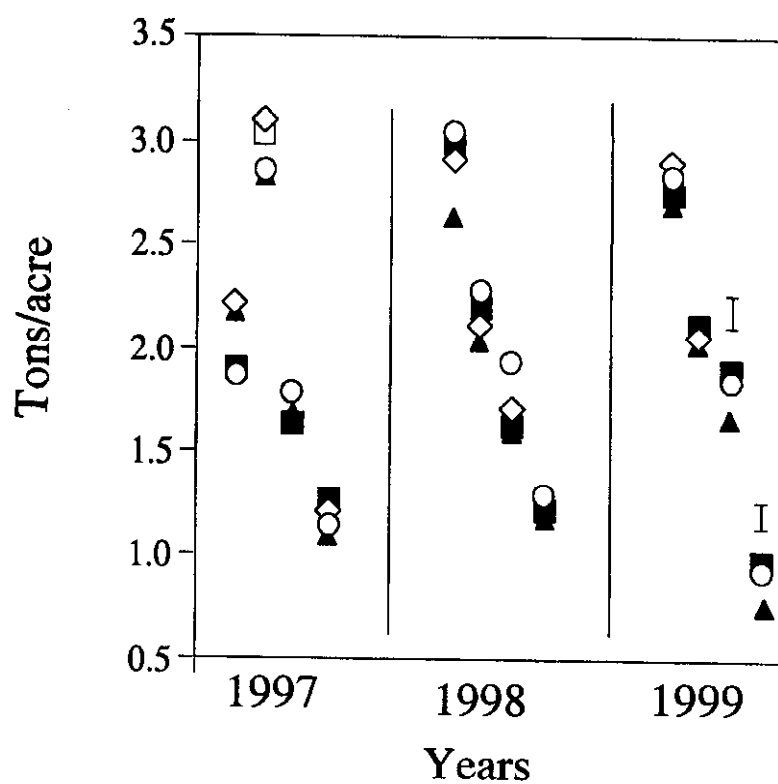


Fig. 1. Alfalfa yield at each harvest as affected by no traffic after swathing (■), 22% of the plot trafficked (◇), 44% of the plot trafficked (○), and 89% of the plot trafficked (▲) 7 days after swathing. Vertical bars represent LSD at the 0.05 probability level.

FIELD PERFORMANCE OF ALFALFA HAY PRESERVATIVES IN WESTERN COLORADO

Dr. Calvin H. Pearson

SUMMARY AND RECOMMENDATIONS

Bacterial inoculants have become more widely marketed in recent years for preserving alfalfa hay when it is baled at high moisture contents. The effectiveness of bacterial inoculants as reliable hay preservatives has been questioned. A field study was conducted to evaluate the effect of hay preservatives on alfalfa hay baled at high moistures (20%+). The study was conducted in two separate years at the Western Colorado Research Center at Fruita. Treatments were: 1) Biotal Hay Inoculant, 2) Forco Hay Conditioner, 3) Germain's Silax 100 Water Soluble Forage Inoculant, 4) untreated high moisture check (20 to 25% moisture), and 5) an untreated low moisture check (12 to 15%). Treatments were applied to the first and third cuttings in 1995 and to the second and the third cuttings in 1997. Based on the results of this study, there was no consistent advantage for routinely applying hay preservatives; however, the data also suggest that under certain, but as yet unspecified conditions, application of a hay preservative may be somewhat beneficial. A thorough understanding of the hay curing process is hindered by many factors that are highly interactive. Routine applications of a hay preservative may have beneficial results some of the time, but being able to ascertain the precise conditions when the application of a hay preservative is needed will require further, detailed research into specific aspects of how preservatives affect hay during the curing process. The results of this study also showed no clear advantage of one product over another. Aside from the effect of hay preservatives on alfalfa hay, applying hay preservatives in a water mixture was much less convenient than applying a dry product through the Gandy applicator.

INTRODUCTION AND OBJECTIVES

Harvest losses can have a dramatic effect on yield and quality of alfalfa hay, resulting in significant monetary loss. Harvest losses in alfalfa hay can occur from at least two major sources: weather and mechanical. Harvest losses from mechanical sources can range from 10 to 50%, and sometimes more. Losses from mechanical sources can be reduced considerably when proper management is used. From the time it is swathed until it is baled, alfalfa is vulnerable to adverse weather conditions that can affect hay yield and quality. Weather-related losses are considered by many growers to be beyond their control. However, management practices can be used to manage potential weather-related losses. Reducing the time from swathing to baling can decrease the risk of alfalfa being damaged by adverse, weather-related events.

Harvest losses in alfalfa hay can be reduced by baling at higher moisture contents. Baling at higher moisture contents prevents harvest losses from these two major sources. Alfalfa baled at higher moisture contents is less likely to experience mechanical harvest losses resulting from field operations that cause dry matter losses, most of which is leaf shattering. Baling at a higher moisture content also shortens the time hay lays in the field and this decreases the potential for

hay to experience adverse weather conditions. However, baling at higher moisture contents without controlling microbial activity is likely to promote excessive microbial decomposition. Hay preservatives have been marketed as products that allow baling at higher moisture contents by preventing the growth of undesirable microbes, mainly fungi and bacteria.

Hay preservatives include several products, including propionic and other organic acids, buffered acid mixtures, anhydrous ammonia and urea, and bacterial inoculants (Shanahan and Smith, 1993; Miller and Rotz, 1995). Bacterial inoculants have become more widely marketed in recent years because, unlike others hay preservative products, they are not corrosive, are easy to apply, and can be applied economically. However, the effectiveness of bacterial inoculants as reliable hay preservatives has been questioned. Furthermore, previous research results with inoculants have been mixed (Rotz et al., 1988; Miller and Rotz, 1995; Horrocks, 1999). The objective of this study was to evaluate three hay preservative products applied to alfalfa hay baled at high moisture contents (20%+). Two products were microbial materials, and one was considered to be a nutritional product. The nutritional product is marketed as a material that promotes the growth of desirable organisms.

MATERIALS AND METHODS

A field study was conducted to evaluate the effect of hay preservatives on alfalfa hay baled at high moistures (20%+). The study was conducted in two separate years at the Western Colorado Research Center at Fruita. The alfalfa field in 1995 was two years old and the field in 1997 was one year old.

Treatments were: 1) Biotol Hay Inoculant applied at approximately 25% hay moisture. Biotol hay inoculant contains two proprietary strains of *Pediococcus pentosaceus*. Application rate of Biotol was 4 grams of product per ton of alfalfa hay as per the manufacturer's recommendations, 2) Forco Hay Conditioner applied at approximately 25% hay moisture. Forco is a proprietary formulation that is reported to contain fermentation products and enzymes that favor the growth and performance of bacteria and fungi that are necessary for proper fermentation of baled forages. Forco was applied at the manufacturer's recommended rate of 2 pounds per ton of hay, 3) Germain's Silax 100 Water Soluble Forage Inoculant applied at approximately 25% hay moisture. Germain's Silax 100 contains lactic acid producing organisms of *Lactobaccillus*, *Streptococcus*, and *Pediococcus* bacteria species. Application rate of Germain's was 20 grams of product per ton of alfalfa hay according to the manufacturer's recommended rate, 4) untreated high moisture check (25% moisture), and 5) an untreated low moisture check (12 to 15%).

Treatments were applied to the first (June 10) and third (September 1) cuttings in 1995 and to the second (July 2) and the third (August 21) cuttings in 1997. Biotol and Germain's products were applied through separate sprayers mounted on the baler with three-nozzle booms that directed applications onto the hay as the windrow entered the baler. The Forco product was a dry material that was applied using a Gandy applicator mounted on top of the baler at the back near the intake of the plunger chamber. A small hole was cut in the top of the baler at the back of the baler near the intake of the plunger chamber and a hose ran from the Gandy box through the hole in the baler and delivered Forco product onto the hay as it entered the plunger chamber.

Treatments were applied randomly one windrow at a time until more than 42 bales of each treatment were made. Generally, treatments were applied to approximately 60 bales.

Immediately after baling, moistures for bales of each treatment were determined with a hand-held probe. Each bale was probed in six equidistant spacings along the cut side of the bale. Once bale moistures were determined, moisture contents of each bale were reviewed and 42 bales were selected that met the criteria of the treatment, that is, bales with approximately a 25% average moisture content with highs not exceeding 30% moisture. Each bale was numbered and tagged to maintain its identity. The untreated low moisture check treatment was baled a day or two later when hay moistures reached 12 to 15%. Alfalfa windrows in the same field as other treatments were reserved for the low moisture treatment.

Bales were transported from the field and stacked 5 layers high, 8 bales to a layer, with two bales on top. Bales of each treatment were stacked similarly by position in each layer within the stack. Eight bales of each treatment were randomly selected, labeled, weighed, and stacked in Layer 3. These eight bales in Layer 3 of the haystack were reweighed during bale evaluation to determine weight loss (shrinkage).

Once the hay was stacked, the top portion of the stack was covered with a tarp to prevent rain damage. The two bales on top of the stack formed a peak to shed water off the stack. Hay bales were stacked on pallets to prevent damage from occurring to bottom bales. Four, 19-inch compost thermometers were inserted into each stack (one thermometer on each side of the stack). The location of the thermometers in each stack was the same. Temperatures were recorded manually each day at the same time of day for the first several days following stacking.

Hay bales were cored the same day they were stacked, and again at the time bales were evaluated. Six end bales from each of the four sides of the bottom portion of the stack were probed. Each side of the stack represented a replication. The same bales were cored at both sampling times using a Penn State forage sampling probe that was powered by an engine drill. Core samples from each bale of the same replication were thoroughly mixed, placed in zip-lock plastic bags, and remained frozen until forage quality was determined. Forage analyses were performed using wet chemistry from the accredited laboratory of W-L Research, 8701 Hwy 14, Evansville, WI 53536 (608-882-4100). Determinations included neutral detergent fiber, acid detergent fiber, digestible dry mater, dry matter intake, and relative feed value.

Bale evaluation did not occur before bales had been in the stack for at least 60 days. Bale evaluation for the first cutting in 1995 occurred on August 24 and for the third cutting on November 7. Bale evaluation for the second cutting in 1997 occurred on November 10. The third cutting was evaluated on November 11, 1997. Two people conducted separate bale evaluations. The results of both evaluations were averaged prior to statistical analysis of the data. All 42 bales were evaluated for percent of the bale that was moldy, for color (scale 1 to 5 with 1 = poor and 5 = excellent), for odor and condition (scale 1 to 5 with 1 = poor and 5 = excellent), and for leaf retention (scale 1 to 5 with 1 = poor and 5 = excellent). A hay quality index using color, odor and condition, and leaf retention ratings was calculated by: color rating X odor and condition rating X leaf retention rating). Using this formula, the index for hay quality had the potential to range from 1 to 125.

RESULTS AND DISCUSSION

Bale moistures for each treatment at the time hay preservatives were applied, standard deviation of bale moistures for each treatment, and high bale moisture contents are shown in

Table 1. The Forco and Germain's treatments had higher average bale moistures than Biotol and the Wet Control in the first cutting in 1995. Average bale moisture contents for Biotol and the Wet Control were not significantly different. The Dry Control had an average bale moisture of 13.1%.

In the third cutting in 1995, average bales moistures for Biotol, Forco, and Germain's were not statistically different. Average bale moisture for the Wet Control was significantly lower than the treatments of the three products. The dry control in the third cutting in 1995 had an average bale moisture of 12.3%. Average bale moistures of all five treatments in the second cutting in 1997 were statistically different from each other. The ranked order from highest to lowest for average bale moisture of the five treatments was Biotol, Germain's, Forco, Wet Control, and Dry Control. In the third cutting in 1997, average bale moistures for Forco and Wet Control were not statistically different. Biotol had the highest average bale moisture. The average bale moisture in the Germain's treatment was significantly lower than for the Biotol treatment but significantly higher than those of the Forco and Wet Control treatments. Average bale moisture in the Dry Control in the third cutting in 1997 was 12.4%. These data clearly illustrate the difficulty in obtaining similar and consistent bale moistures when applying hay preservatives and the difficulty in obtaining similar bale moistures from cutting to cutting.

Standard deviations among the treatments were also significantly different for three of the four cuttings evaluated (Table 1). In the second cutting in 1997, differences in standard deviations among Biotol, Forco, Germain's, and Wet Control treatments were not statistically significant. As would be expected, the standard deviation of the Dry Control in the second cutting in 1997 was significantly lower than in other treatments. This result of the Dry Control having a lower standard deviation than the other treatments also occurred in the other cuttings.

High readings for bale moisture contents were also not consistent for hay preservative treatments in the four cuttings (Table 1). In the first cutting in 1995, Forco and Germain's had significantly higher average high bale moisture contents than the Wet Control and Biotol. In the third cutting in 1995, Forco had a higher average high bale moisture content than other treatments, and Germain's and Biotol had higher average high bale moisture contents than the Wet Control and the Dry Control. In the second cutting in 1997, Biotol had a higher average high bale moisture content than the other treatments. There were no statistically significant differences among average high bale moisture contents for Germain's, Forco, and Wet Control. Average high bale moisture contents for Biotol and Germain's in the third cutting in 1997 were similar. Average high bale moisture contents for Forco and Wet Control were also similar, but significantly lower than average high moisture content for Biotol and Germain's in the third cutting in 1997. Similar to the average bale moisture contents, the average high bale moisture contents for the Dry Control were significantly lower than the other treatments. The result of the Dry Control having a lower average high bale moisture content was consistent in all four cuttings evaluated.

The amount of mold observed in the first cutting in 1995 was similar to the Wet Control, Germain's, and Biotol treatments (Table 1). The Forco treatment had a significantly lower amount of mold than the Wet Control, Germain's, and Biotol treatments by nearly 32 percentage points. In the third cutting in 1995, the amount of mold in Biotol, Forco, and Germain's was similar. The Wet Control had a significantly lower amount of mold than Biotol and Forco in the third cutting in 1995 by more than 10 percentage points. Overall, the amount of mold found in

the second cutting in 1997 was low, averaging less than 3%. However, the Wet Control had a significantly higher amount of mold than the other treatments. The amount of mold found in the other four treatments was similar. The average moisture contents in the second cutting in 1997 were considerably lower than those of the other three cuttings. In the third cutting in 1997, Germain's and Biotol had similar amounts of mold. The Wet Control and Forco also had similar amounts of mold and were nearly 16 percentage points lower than mold in the Germain's and Biotol treatments.

Hay quality index was calculated using hay quality characteristics of leaf retention, odor and condition, and hay color (Table 1). Hay quality index in the first cutting in 1995 was highest for the Dry Control. Quality index was similar for Forco and Wet Control but significantly lower than the Dry Control. Biotol had a lower quality index than the Dry Control, Forco, and the Wet Control, and Germain's had a lower quality index than Biotol. In the third cutting in 1995, the Wet Control had the highest hay quality index. Biotol and Forco had similar quality, but the quality indices were lower than the Wet Control. Forco and Germain's also had similar hay quality indices. The Dry Control in the third cutting in 1995 had the lowest hay quality index. In the second cutting in 1997, Forco had the highest hay quality index score. The Wet Control, Biotol, and Germain's had similar quality indices, but they were lower than that of Forco. The Dry Control had the lowest hay quality index in the second cutting in 1997. In the third cutting in 1997, Forco again had the highest hay quality index score as compared to the other treatments. Biotol and Wet Control had similar hay quality indices, but they were lower than Forco, and Biotol and Germain's had similar indices that were lower than the Wet Control. The Dry Control had the lowest hay quality index in the third cutting in 1997.

Eight bales from each treatment were randomly selected to determine bale weight loss during storage in the stack. These data are presented in Table 2. Average hay moistures of these bales differed among the treatments and cuttings similar to what was observed in bale moistures in Table 1, with the exception that bale moisture among Biotol, Forco, Germain's, and Wet Control was similar in the third cutting in 1995. Average weights of the randomly selected bales were significantly different among the treatments and the ranked order of the treatments also varied with cutting (Table 2). This indicates that while there were significant differences among the treatments, bale weight was not biased in favor of any particular treatment. This same situation also applies to bales that were weighed following storage as shown by the data for bale weight after storage (Table 2). The weight bales lost during storage ranged from as low as 0.5 pound per bale to as much as 12 pounds per bale. The pounds of bale weight loss were similar for Biotol, Forco, Germain's, and Wet Control in the first cutting in 1995, third cutting in 1995, and the third cutting in 1997, although the actual number of pounds of loss may have been different among the cuttings. In the second cutting in 1997, pounds of bale loss were similar for Germain's, Biotol, and Wet Control. Bale weight loss for Forco and Wet Control was similar but lower than Biotol and Germain's. The bale weight loss for Forco was significantly lower than those of Germain's and Biotol. Compared to the other treatments in all four cuttings, the Dry Control had the lowest amount of bale weight loss. The percent bale weight loss was not as consistent among treatments and cuttings as the actual loss by weight in pounds (Table 2), although the Dry Control consistently had the lowest amount of percent weight loss compared to the other treatments.

Forage quality characteristics were determined when bales of each treatment were stacked and again when bales of each treatment were evaluated following storage. Data were obtained for neutral detergent fiber (NDF), acid detergent fiber (ADF), digestible dry matter (DDM), dry matter intake (DMI), and relative feed value (RFV). These data are presented in Table 3. The * represents significant differences between the before and after quality analysis at the 10% level of probability. In the first and third cuttings in 1995, there were no significant differences among the treatments for NDF, ADF, DDM, DMI, or RFV (Table 3). Most forage quality characteristics were affected significantly during storage, regardless of treatments, in the first and third cuttings in 1995. NDF and ADF increased and DDM decreased slightly but significantly in both the first and third cuttings in 1995. In the first cutting in 1995, DMI was not affected significantly during storage, but was significantly decreased during storage in the third cutting in 1995. RFV also was not affected during storage in the first cutting in 1995, but was lowered significantly during storage in the third cutting in 1995.

Forage quality characteristics were affected significantly by treatments in both cuttings in 1997 (Table 3). However, there was no consistent response of the treatments to the forage quality characteristics for each of the two cuttings evaluated in 1997 and there was no clear indication that alfalfa hay treated with a hay preservative had an advantage in hay quality over the Wet Control. Based on the data from the two cuttings in 1997, there was a trend for the Dry Control to have poorer hay quality than the other treatments.

Bale temperatures for each of the treatments in the four cuttings are shown in Fig. 1. These data provide good visual evidence on how bale temperatures varied with each cutting. Bale temperatures are highly dependent of the environmental conditions that hay is subjected to each cutting. Bale temperature data serve to illustrate the response that occurs in each cutting and the responses of the treatments within and across cuttings. Similar responses were much the same for other characteristics evaluated in this study.

This study was conducted under conditions similar to those that growers are likely to experience during haymaking. In summary, based on the results obtained for all four cuttings, there was no consistent advantage for routinely applying hay preservatives; however, the data also suggest that under certain, but as yet unspecified conditions, application of a hay preservative may be somewhat beneficial. A thorough understanding of the hay curing process is hindered by many factors that are highly interactive. The results of this research do point to the importance of packaging alfalfa hay at the proper moisture content and how sensitive hay moisture is to haymaking and how rapidly hay moisture can change during haymaking. Routine applications of a hay preservative may have beneficial effects some of the time, but being able to ascertain the precise conditions that would dictate when an application of a hay preservative is needed will require further, detailed research into specifics aspects of how preservatives affect hay during the curing process.

Based on the results of this study, there was no clear advantage of one product over another. Aside from the effect of hay preservatives on alfalfa hay, applying hay preservatives in a water mixture was much less convenient than applying a dry product through the Gandy applicator. Product cost is also a consideration in the decision-making process. The purchase price of a 50-pound bag of Biotol is \$84.95 (\$1.69 per pound), a 50-pound bag of Forco is \$112.50 (\$2.25 per pound), and a 50-pound bag of Germain's is \$57.50 (\$1.15 per pound). The Germain's water soluble hay preservative is \$58.00 for an equivalent amount needed to treat as much hay as would be accomplished with a 50-lb bag of the dry material.

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LITERATURE CITED

- Horrocks, R. Dwain, and John F. Vallentine. 1999. Harvested forages. Academic Press. San Diego, California, pps. 258-262
- Miller, D.A., and C. A. Rotz. 1995. Harvesting and storage. *In*: Barnes, Robert F., Darrell A. Miller, and C. Jerry Nelson (eds.) Forages, Volume 1: An introduction to grassland agriculture (5th ed.). Iowa State Univ. Press. Ames, Iowa, pps. 163-174.
- Rotz, C.A., R.J. Davis, D.R. Buckmaster, and J.W. Thomas. 1988. Bacterial inoculants for preservation of alfalfa hay. *J. Prod. Agric.* 1:362-367.
- Shanahan, J.F., and D.H. Smith. 1993. Hay preservation systems. Colo. State Univ. Coop. Ext., Colo. State Univ., Fort Collins, Colorado, No. 0.705.

Table 1. Bale moisture, standard deviation of bale moisture, high bale moisture content, mold in bales, and bale quality index of hay preservatives applied to alfalfa hay at the Western Colorado Research Center at Fruita in 1995 and 1997. Data are averages of 42 alfalfa bales per treatment.

Hay preservative	Bale moisture	Standard deviation of bale moisture	High bale moisture content	Mold in bales	Bale quality index
-----%-----					
First cutting 1995					
Biotol	22.3	4.0	28.3	58.7	21.8
Forco	22.8	4.9	31.0	31.1	28.8
Germain's	23.1	4.5	30.0	64.7	17.3
Wet control	22.0	4.8	29.5	65.4	27.5
Dry control	13.1	1.8	16.1	2.8	35.4
LSD (0.10)	0.5	0.6	1.4	8.9	3.8
Third cutting 1995					
Biotol	21.8	3.0	26.1	25.3	36.0
Forco	22.7	4.3	29.8	21.0	32.6
Germain's	22.0	3.6	27.5	20.3	30.2
Wet control	20.6	3.5	26.1	12.9	41.5
Dry control	12.3	0.5	13.1	0.3	14.8
LSD (0.10)	0.9	0.5	1.4	7.9	4.0
Second cutting 1997					
Biotol	19.6	4.6	27.5	1.4	55.6
Forco	17.8	4.3	24.7	1.4	68.2
Germain's	18.5	4.1	25.5	2.1	53.4
Wet control	17.1	4.1	24.1	7.9	58.3
Dry control	12.3	0.5	13.3	1.0	37.8
LSD (0.10)	0.3	0.7	1.5	2.8	5.6
Third cutting 1997					
Biotol	24.1	4.0	30.3	23.4	26.6
Forco	23.1	3.8	28.9	10.4	33.4
Germain's	23.8	4.1	30.3	29.3	24.9
Wet control	22.9	3.5	28.5	11.0	28.4
Dry control	12.4	3.0	16.6	0.3	21.4
LSD (0.10)	0.3	0.5	1.1	6.5	2.2

Table 2. Bale weight at stacking, bale weight after storage, and bale weight loss of hay preservatives applied to alfalfa hay at the Western Colorado Research Center at Fruita in 1995 and 1997. Data are averages of 8 alfalfa bales per treatment.

Hay preservative	Bale moisture at stacking %	Bale weight at stacking -----lbs-----	Bale weight after storage	Bale weight loss	Bale weight loss %
<u>First cutting 1995</u>					
Biotol	20.9	72.8	63.2	9.6	12.8
Forco	23.9	73.4	63.2	10.2	13.2
Germain's	25.0	77.8	65.6	12.2	15.5
Wet control	20.8	70.3	61.4	8.9	12.5
Dry control	13.1	63.8	60.8	3.1	4.8
LSD (0.10)	3.0	5.0	2.5	3.8	4.3
<u>Third cutting 1995</u>					
Biotol	23.2	75.2	70.4	4.8	5.9
Forco	22.0	71.2	66.3	4.9	6.3
Germain's	21.9	73.4	69.2	4.2	5.3
Wet control	20.0	63.7	58.5	5.2	8.1
Dry control	12.5	55.2	53.9	1.3	2.4
LSD (0.10)	3.7	9.7	7.7	2.5	2.6
<u>Second cutting 1997</u>					
Biotol	20.1	73.6	69.5	4.2	5.6
Forco	17.9	68.5	65.6	2.9	4.2
Germain's	19.5	82.2	77.7	4.5	5.5
Wet control	17.0	69.8	66.2	3.6	5.0
Dry control	12.3	62.1	61.6	0.5	0.8
LSD (0.10)	1.5	6.5	5.8	1.1	1.3
<u>Third cutting 1997</u>					
Biotol	23.8	86.4	81.4	5.0	5.7
Forco	24.2	84.9	78.4	6.5	7.7
Germain's	24.3	86.4	80.8	5.7	6.4
Wet control	21.6	66.1	60.3	5.7	8.6
Dry control	12.2	58.4	57.9	0.6	1.0
LSD (0.10)	2.1	5.1	4.2	1.8	2.1

Table 3. Forage quality of alfalfa hay treated with preservatives at Fruita, Colorado 1995 and 1997.

Hay Preservative	Neutral detergent fiber (NDF)			Acid detergent fiber (ADF)			Digestible dry matter (DDM)		
	-----% of dry matter-----			-----% of dry matter-----			-----% of dry matter-----		
	Before	After	Ave.	Before	After	Ave.	Before	After	Ave.
<u>First cutting 1995</u>									
Biotol	41.6	43.6	42.6	31.9	33.7	32.8	64.0	62.7	63.4
Forco	42.9	43.1	43.0	32.8	33.3	33.0	63.4	63.0	63.2
Germain's	42.2	42.3	42.2	32.3	32.9	32.6	63.8	63.3	63.5
Wet control	41.7	44.3	43.0	32.1	34.0	33.0	63.9	62.4	63.2
Dry control	40.8	41.2	41.0	31.2	31.8	31.5	64.6	64.1	64.4
Ave.	41.8	42.9*		32.1	33.1*		63.9	63.1*	
LSD (0.10)	NS			NS			NS		
<u>Third cutting 1995</u>									
Biotol	39.6	45.0	42.3	31.4	34.3	32.9	64.4	62.2	63.3
Forco	40.7	43.7	42.2	32.4	34.1	33.2	63.6	62.4	63.0
Germain's	41.0	46.1	43.6	32.5	34.6	33.5	63.6	62.0	62.8
Wet control	41.1	44.3	42.7	32.3	34.1	33.2	63.8	62.4	63.1
Dry control	40.3	43.4	41.8	32.1	33.4	32.7	63.9	62.9	63.4
Ave.	40.5	44.5*		32.1	34.1*		63.9	62.4*	
LSD (0.10)	NS			NS			NS		
<u>Second cutting 1997</u>									
Biotol	38.4	38.7	38.6	28.2	28.3	28.3	66.9	66.8	66.9
Forco	38.4	41.3	39.9	28.7	30.2	29.5	66.5	65.4	65.9
Germain's	39.5	40.6	40.1	29.5	30.1	29.8	65.9	65.5	65.7
Wet control	38.1	41.4	39.7	28.1	30.9	29.5	67.0	64.8	65.9
Dry control	45.4	46.8	46.1	34.6	35.4	35.0	61.9	61.3	61.6
Ave.	40.0	41.8*		29.8	31.0*		65.7	64.7*	
LSD (0.10)	1.8			1.5			1.1		
<u>Third cutting 1997</u>									
Biotol	42.6	44.0	43.3	32.3	32.9	32.6	63.8	63.3	63.5
Forco	44.1	46.3	45.2	33.7	35.5	34.6	62.7	61.2	61.9
Germain's	43.1	44.4	43.8	33.0	33.8	33.4	63.2	62.6	62.9
Wet control	40.1	44.6	42.3	30.5	34.0	32.2	65.2	62.4	63.8
Dry control	43.0	45.1	44.0	32.8	34.3	33.6	63.3	62.2	62.7
Ave.	42.6	44.9*		32.5	34.1*		63.6	62.3*	
LSD (0.10)	1.6			1.3			1.0		

Table 3 (continued). Forage quality of alfalfa hay treated with preservatives at Fruita, Colorado 1995 and 1997.

Hay Preservative	Dry Matter Intake (DMI)			Relative feed value (RFV)		
	-----% of body weight-----					
	Before	After	Ave	Before	After	Ave.
First cutting 1995						
Biotol	2.9	2.8	2.8	143.3	133.8	138.5
Forco	2.8	2.8	2.8	138.0	135.8	136.9
Germain's	2.8	2.9	2.9	140.5	141.8	141.1
Wet control	2.9	2.7	2.8	143.0	130.8	136.9
Dry control	2.9	2.9	2.9	147.5	145.0	146.3
Ave.	2.9	2.8		142.5	137.4	
LSD (0.10)			NS			NS
Third cutting 1995						
Biotol	3.0	2.7	2.9	151.8	128.8	140.3
Forco	2.9	2.8	2.8	145.8	133.3	139.5
Germain's	2.9	2.6	2.8	144.8	126.8	135.8
Wet control	2.9	2.7	2.8	144.3	131.0	137.6
Dry control	3.0	2.8	2.9	147.5	135.3	141.4
Ave.	3.0	2.7*		146.8	131.0*	
LSD (0.10)			NS			NS
Second cutting 1997						
Biotol	3.1	3.1	3.1	162.3	160.8	161.5
Forco	3.1	2.9	3.0	161.2	148.1	154.7
Germain's	3.0	3.0	3.0	155.6	150.6	153.1
Wet control	3.2	2.9	3.0	164.0	145.9	155.0
Dry control	2.6	2.6	2.6	127.1	122.3	124.7
Ave.	3.0	2.9*		154.0	145.5*	
LSD (0.10)			0.1			8.9
Third cutting 1997						
Biotol	2.8	2.7	2.8	139.4	134.1	136.7
Forco	2.7	2.6	2.7	132.5	123.3	127.9
Germain's	2.8	2.7	2.7	136.6	131.5	134.1
Wet control	3.0	2.7	2.8	151.6	130.4	141.0
Dry control	2.8	2.7	2.7	137.2	128.4	132.8
Ave.	2.8	2.7*		139.4	129.6*	
LSD (0.10)			0.1			6.9

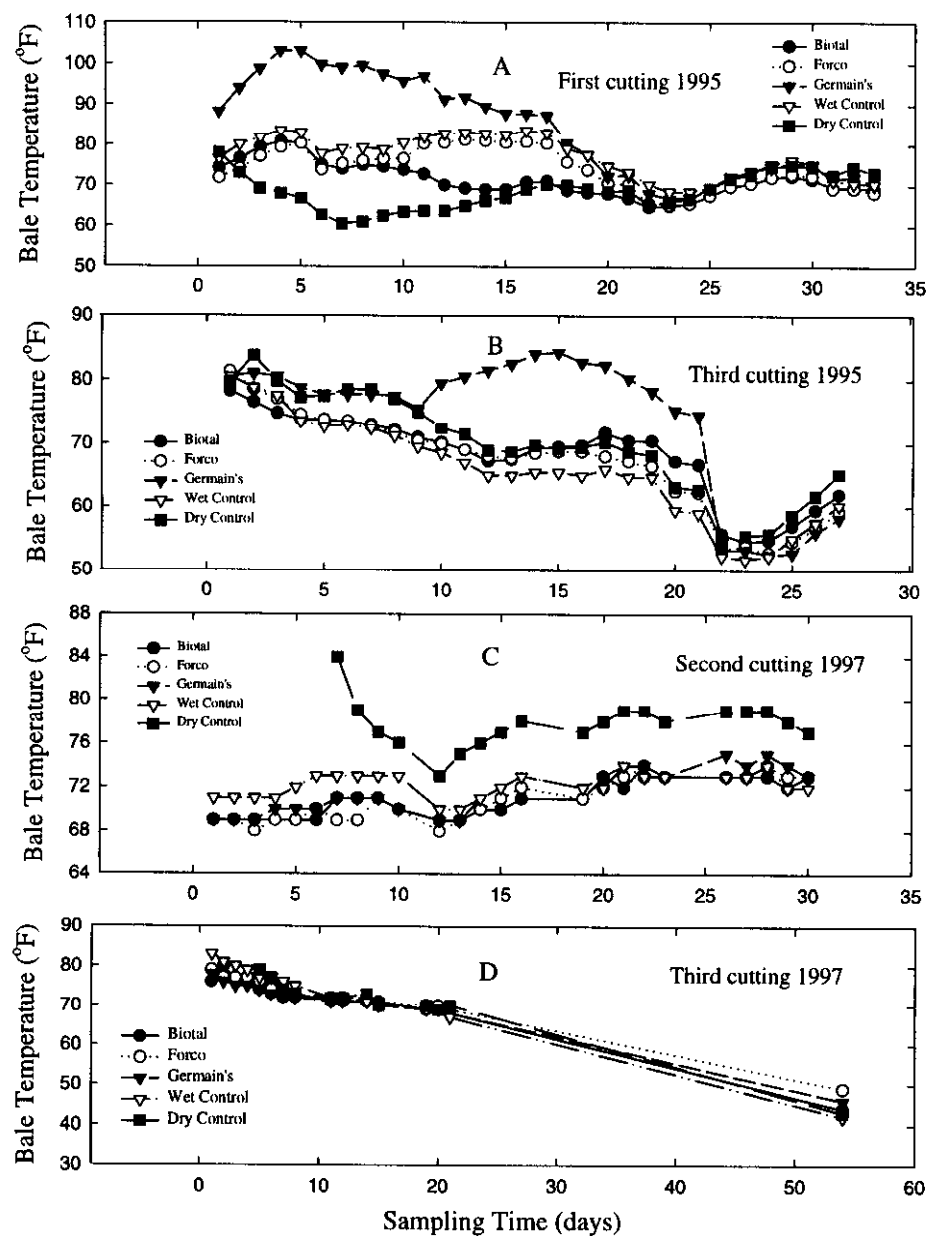


Fig. 1. Bale temperatures of hay preservatives at Fruita, Colorado in 1995 and 1997.

ALFALFA RESPONSE TO BORON FERTILIZATION

Jessica G. Davis, Abdel Berrada, and Ron F. Meyer

SUMMARY AND RECOMMENDATIONS

Alfalfa is considered to be a crop with a high boron (B) requirement; however, several Great Plains states do not recommend any B fertilizer for alfalfa due to the lack of documented B deficiencies or responses to B fertilizer in this region. The purpose of this project was to evaluate the impact of B fertilizer rates on irrigated alfalfa yield on two soils where a B response was likely, due to low soil B levels. Boron was applied at five rates (0, 0.5, 1, 2, and 4 lbs B/acre), treatments were replicated at least four times in a randomized complete block design at each of two locations, and yields were measured. In four site-years of research, there was no significant difference in alfalfa yield due to B fertilization. This is probably due to the B supplied in the irrigation water. As little as 0.3 ppm B in the irrigation water would supply alfalfa with 2 lbs B/acre. A survey of 92 Colorado wells showed an average B concentration of 0.52 ppm B; therefore, the irrigation water is probably providing adequate B for optimum alfalfa production. Results of this study suggest that knowledge of the B concentration in irrigation water, as well as soil test B levels, should be used to determine whether B fertilizer needs to be applied to irrigated alfalfa.

INTRODUCTION AND OBJECTIVES

Boron (B) deficiency symptoms in alfalfa are sometimes described as "yellow-top." The younger leaves turn yellow or red between the veins, rosetting develops due to shortened stems, and ultimately, the terminal bud dies. Back in the 1930's, Willis and Piland (1938) and Colwell and Baker (1939) demonstrated that borax application corrected these yellowing symptoms in alfalfa. Early on, soil test critical levels were defined as either 1 ppm of available B (Dregne and Powers, 1942) or 0.15 ppm hot-water-soluble B (Rogers, 1947b). Rogers (1947a) measured an average yield increase of 58% on B-responsive fields. These early studies were done on a broad range of soils from North Carolina and Alabama to Idaho and Oregon.

Alfalfa is considered to be a crop with a high B requirement, and recommended rates vary from 0.9-3.6 lbs B/acre (Mortvedt and Woodruff, 1993). However, the land grant universities in Colorado (Mortvedt et al., 1996), Utah, Wyoming, and North Dakota do not recommend any B fertilizer for alfalfa (Mortvedt and Woodruff, 1993). Meanwhile, recent research in Texas reported alfalfa yield increases due to B application (Haby et al., 1998). So why do many Great Plains states recommend no B fertilizer for alfalfa? The stated reason in Colorado State University's Fertilizer Suggestions for Alfalfa (Mortvedt et al., 1996) is that no confirmed B deficiency has ever been documented in the state.

The purpose of this project was to evaluate the impact of B fertilizer rates on irrigated alfalfa yield on soils where a B response was most likely, specifically in soils with low B levels, low organic matter levels, and coarse textures.

MATERIALS AND METHODS

We sought out soils with low B levels, low organic matter levels, and coarse textures and settled on two locations: one in southwestern Colorado near Yellow Jacket and the other in northeastern Colorado in the sandhills near Holyoke. The soil types were Julesburg sandy loam (coarse, loamy, mixed, mesic Aridic Argiustoll) in Holyoke and Wetherill silty clay loam (fine-silty, mixed, superactive, mesic Aridic Haplustalf) in Yellow Jacket. These soils were tested for available (hot water soluble) B, soil organic matter content, and cation exchange capacity (Table 1).

Alfalfa at both sites was established in 1995 and irrigated via center pivot. The alfalfa varieties were Pioneer 5454 at Holyoke and Archer at Yellow Jacket. Fertilizer was applied as follows: 75 lbs P_2O_5 /acre in 1997 in Yellow Jacket; 75 lbs P_2O_5 /acre and 150 lbs K_2O /acre in 1998 in Holyoke; 75 lbs P_2O_5 /acre, 150 lbs K_2O /acre, and 35 lbs S/acre in 1999 in Holyoke. Boron was applied at five rates (0, 0.5, 1, 2, and 4 lbs B/acre) onto the alfalfa foliage as a spray of *Solubor* in April of each year, with the same B treatments applied on the same sites in the second year. Boron was applied using a CO_2 powered backpack sprayer. The spray application was used to obtain a uniform B application on each plot. The 4 lb/acre rate was split into two applications approximately one week apart in order to avoid burning the plants.

Treatments were replicated in a randomized complete block design, with four replicates in Holyoke and five replicates in Yellow Jacket. Yields were measured at each harvest (Table 2). Individual plot size was 6 by 21 ft in Holyoke and 10 by 40 ft in Yellow Jacket. Alfalfa was harvested using a self-propelled forage harvester with a sickle bar mower (a Jerri mower was used in 1998 in Holyoke). Sub-samples were taken at harvest, weighed immediately, re-weighed after drying, and dry matter percentages were calculated. Harvest yields were corrected to a dry matter basis.

RESULTS AND DISCUSSION

There was no significant impact of B fertilizer application on alfalfa yield for any of the cuttings in any of the four site-years (Tables 3-6). Yield reductions were noted in 1999 from the third and fourth cuttings at the Holyoke location (Table 6). The aging stand and later harvest maturities (60% bloom) probably combined with higher than normal air temperatures in August and September to cause these yield reductions.

Why were there no yield responses to B fertilization on low B soils in this study? Perhaps the irrigation water is supplying the necessary B to the alfalfa crop. A survey of 92 wells in northeastern Colorado revealed an average of 0.52 ppm B in the irrigation water, with a range from 0.03 to 2.30 ppm B. Based on 30 inches of consumptive water use by alfalfa, 0.3 ppm B in irrigation water would provide alfalfa's required 2 lbs B/acre (see calculation below). Therefore, irrigation water may be providing the necessary B, thus preventing a response to B fertilizer, even on soils testing low in available B.

However, the B level in the irrigation water at Yellow Jacket was 0.02 ppm, a level low enough to suspect that a B fertilizer response would be evident.

Calculation

Use the amount of consumptive water use for alfalfa in your region and multiply it by a correction factor of 2.7 million pounds of water per acre-foot. Finally, multiply that by the measured B concentration in ppm in the irrigation water. This results in the B application in lbs/acre.

$$\frac{30 \text{ inches of water}}{12 \text{ inches/acre-foot}} \times \frac{2.7 \text{ million pounds water}}{\text{acre-foot}} \times 0.3 \text{ ppm B} = 2.0 \text{ lbs B/acre}$$

The same type of calculation can be made for any nutrient contained in irrigation water (nitrate, sulfate, etc.).

ACKNOWLEDGMENTS

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LITERATURE CITED

- Colwell, W.E., and G.O. Baker. 1939. Studies of boron deficiency in Idaho soils. *J. Am. Soc. Agron.* 31:503-512.
- Dregne, H.E., and W.L. Powers. 1942. Boron fertilization of alfalfa and other legumes in Oregon. *J. Am. Soc. Agron.* 34:902-912.
- Haby, V., J.V. Davis, and A. Leonard. 1998. Alfalfa response to boron at variable soil pH on coastal plain soils. *Better Crops with Plant Food* 82: 22-26.
- Mortvedt, J.J., D.H. Smith, and R.L. Croissant. 1996. Fertilizing alfalfa and grasses. *Colo. State Univ. Coop. Ext. factsheet no. 0.537*. Fort Collins, CO.
- Mortvedt, J.J., and J.R. Woodruff. 1993. Technology and application of boron fertilizers for crops. In U.C. Gupta (ed.) *Boron and Its Role in Crop Production*. CRC Press; Boca Raton, LA. pp. 157-176.
- Rogers, H.T. 1947a. Boron response and tolerance of several legumes to borax. *J. Am. Soc. Agron.* 39:897-913.
- Rogers, H.T. 1947b. Water-soluble boron in coarse-textured soils in relation to need of boron fertilization for legumes. *J. Am. Soc. Agron.* 39:914-928.
- Willis, L.G., and J.R. Piland. 1938. A response of alfalfa to borax. *J. Am. Soc. Agron.* 30:63-67.

Table 1. Soil characteristics of the study sites.

Location	Soil Boron	Organic Matter	Cation Exchange Capacity
	ppm	%	cmoles/100 g
Holyoke	0.2	1.2	6
Yellow Jacket	0.4	1.1	22

Table 2. Alfalfa cutting dates and growth stages.

Cuttings	Yellow Jacket		Holyoke	
	1997	1998	1998	1999
First	June 19 (10% bloom)	June 10 (bud to early bloom)	May 28 (late bud)	May 27 (mid bud)
Second	August 15 (full bloom)	July 22 (5-10% bloom)	June 30 (late bud)	June 30 (10% bloom)
Third	October 2 (full bloom)	September 16 (10% bloom)	July 30 (late bud)	July 30 (60% bloom)
Fourth	---	---	September 10 (10% bloom)	September 10 (60% bloom)

Table 3. Alfalfa yield results at Yellow Jacket in 1997.

B Rate	First Cutting	Second Cutting	Third Cutting	Total
lbs/acre	-----tons/acre-----			
0	3.00	2.31	1.44	6.75
0.5	2.73	2.37	1.44	6.54
1.0	2.85	2.33	1.40	6.58
2.0	2.74	2.37	1.44	6.55
4.0	2.92	2.32	1.49	6.73

Table 4. Alfalfa yield results at Yellow Jacket in 1998.

B Rate	First Cutting	Second Cutting	Third Cutting	Total
lbs/acre	-----tons/acre-----			
0	2.50	1.95	1.28	5.73
0.5	2.58	1.94	1.31	5.83
1.0	2.54	1.94	1.25	5.73
2.0	2.53	1.94	1.30	5.77
4.0	2.55	1.93	1.34	5.82

Table 5. Alfalfa yield results at Holyoke in 1998.

B Rate	First Cutting	Second Cutting	Third Cutting	Fourth Cutting	Total
lbs/acre	-----tons/acre-----				
0	1.74	1.59	1.30	1.63	6.26
0.5	1.91	1.52	1.32	1.62	6.37
1.0	1.85	1.54	1.26	1.45	6.10
2.0	1.77	1.50	1.24	1.60	6.11
4.0	1.84	1.60	1.19	1.58	6.21

Table 6. Alfalfa yield results (tons dry matter/acre) at Holyoke in 1999.

B Rate	First Cutting	Second Cutting	Third Cutting	Fourth Cutting	Total
lbs/acre	-----tons/acre-----				
0	1.28	1.78	0.84	1.02	4.94
0.5	1.20	1.81	0.89	1.07	4.96
1.0	1.20	1.77	0.88	1.04	4.89
2.0	1.27	1.83	0.90	0.99	4.99
4.0	1.20	1.77	0.84	1.02	4.83

CHEMICAL CONTROL OF ALFALFA STEM NEMATODE AND ALFALFA WEEVIL, FRUITA COLORADO

Robert Hammon

SUMMARY AND RECOMMENDATIONS

A three year experiment investigating the effect of chemical treatment with Furadan 4F on alfalfa stem nematode abundance and hay yield in a stem nematode resistant as well as a susceptible variety was conducted at Fruita, Colorado between 1996 and 1998. Alfalfa growth response to chemical treatment for alfalfa stem nematode and alfalfa weevil varied with variety, stand age and insecticide rate. More alfalfa stem nematodes were extracted from the susceptible than the resistant variety in all treatments except the untreated checks. Stem nematode numbers increased over time in all plots, with the largest change observed between the second and third production years. The greatest yield response to Furadan 4F at 1.0 lb/acre was observed in the alfalfa stem nematode resistant variety in the third production year. Chemical treatments affected yield in only the first cutting of each year. Early season application of Furadan 4F at 1.0 lb/acre is not as effective in controlling alfalfa weevil as Furadan 4F at 0.5 lb/acre applied two weeks before harvest, but was as or more effective than Lorsban 4E at 0.5 lb/acre. The economics of insecticide application varied with year and variety.

INTRODUCTION AND OBJECTIVES

The alfalfa stem nematode complex in the western US consists of two nematode species, Alfalfa stem nematode, *Ditylenchus dispaci*, and Chrysanthemum foliar nematode, *Aphelenchoides ritzema-bosi* (Gray et al. 1994). Stem nematodes, along with alfalfa weevils (*Hypera postica*), are major pests of alfalfa production in the irrigated regions of western Colorado. Management of stem nematodes has been primarily through use of resistant alfalfa varieties, while that of alfalfa weevil with a combination of cultural and chemical methods. Chemical control of alfalfa weevil in western Colorado has been primarily with Furadan 4F, applied at a rate of either 0.25 or 0.5 lb a.i./acre or Lorsban 4E at a rate of 0.5 lb a.i./acre. These insecticides are usually applied two weeks or less before anticipated harvest.

Several non-replicated evaluations of Furadan 4F at a rate of 1.0 lb a.i./acre were done at the Fruita Research Center (Mesa Co, CO) between 1992 and 1995 with mixed results. Evaluations of one and two year old alfalfa fields showed little growth response beyond that expected from alfalfa weevil control. Evaluations in three year old alfalfa stands showed a growth increase beyond that expected from alfalfa weevil control alone. An experiment was initiated in 1996 to determine if the traditional use of Furadan 4F could be modified to control alfalfa stem nematodes as well as alfalfa weevil. We included Alfalfa stem nematode resistant and susceptible varieties to see if chemical management strategies would be the same with different resistance levels in host plants. The experiment was carried out over three years. The objectives were:

- 1) Evaluation of alfalfa stem nematode resistant and susceptible varieties over time, with and without chemical treatments under typical Grand Valley alfalfa stem nematode pressure.
- 2) Economic analysis of chemical control of alfalfa stem nematode over a three year stand life using Furadan 4F applied at 1.0 lb a.i./acre.
- 3) Characterization of alfalfa stem nematode damage and infestation levels over the life of the alfalfa stand.

MATERIALS AND METHODS

The experiment was planted on Sep.12, 1995 at the Fruita Research Center (Mesa Co. CO.) at a seeding rate of 12 lb/acre, with the first harvest during the 1996 growing season. The plots were arranged in a split plot design with variety as the main plot (ASN resistant - WL323; ASN susceptible - Ranger) and chemical treatment as sub-plot. Main plot size was 10 x 150 ft and sub plots were 10 x 25 ft. Chemical treatments were applied before first cutting only, and were:

- 1) Furadan 4F 1.0 lb a.i./acre; ~30 days before harvest (DBH), year 1,2,3
- 2) Furadan 4F 1.0 lb a.i./acre; ~30 DBH, year 2,3, Lorsban 4E 0.5 lb a.i./acre; ~14 DBH year 1
- 3) Furadan 4F 1.0 lb a.i./acre; ~30 DBH, year 3, Lorsban 4E 0.5 lb a.i./acre; ~14 DBH year 1,2
- 4) Lorsban 4E 0.5 lb a.i./acre; ~14 DBH, year 1,2,3
- 5) Furadan 4F 0.5 lb a.i./acre; ~14 DBH, year 1,2,3
- 6) Untreated

Treatments 1, 2 and 3 were designed to determine if there was a cumulative effect of annual applications of Furadan 4F 1.0 lb/acre on stem nematode damage and maintenance of alfalfa stand density. The Furadan 4F 1.0 lb/acre treatment was applied after spring regrowth, approximately one month prior to first cutting. The Lorsban 4E treatment was applied approximately 14 days before harvest and was intended to control alfalfa weevil but not stem nematodes. Furadan 4F 0.5 lb/acre, applied approximately 14 days before harvest is a traditional alfalfa weevil treatment in western Colorado. All sprays were applied with a CO₂ pressured rickshaw type sprayer calibrated to apply 20 gal/acre spray material over a 10 ft spray pattern. Actual spray dates are displayed in Table 1.

Harvests were conducted using a modified John Deere 2280 swather with on-board scales to measure plot weight. Harvest dates are displayed in Table 2. Harvest time moisture was calculated from air dried samples taken at harvest and tons/acre of hay was calculated by multiplying plot weight and harvest moisture.

Alfalfa weevil density was measured in 1997 and 1998 by taking five 180° sweeps with a 15" sweep net prior to first cutting and counting weevil larvae. Alfalfa stem nematode abundance was measured by extracting and preserving nematodes from ten random stems per plot, pulled from crown level, after first cutting regrowth. Nematodes were extracted in Baermann funnels for 24 h before preservation in formaldehyde. Nematodes per gram of plant material were calculated after counting samples under an inverted compound microscope. The alfalfa stand density was measured each year by counting the plants in a 1/4 m² hoop centered

around a permanent metal marker placed in each plot during the spring of 1996. The stand count was conducted at the same location each year of the study.

Analysis of variance was done with MSTAT-C. Stand density, alfalfa stem nematode, and yield data were analyzed in a 3-way analysis (year, variety, chemical), with the chemical treatment a sub-plot of variety. Mean separations were determined using LSD ($\alpha=0.10$). Alfalfa weevil count data was transformed $(X+0.5)^{1/2}$ before analysis as a split plot independent of year. Actual means with LSD mean separation of transformed data ($\alpha=0.05$) are displayed in Table 3.

RESULTS

Experimental means (yield by cutting and annual total, alfalfa stem nematode numbers and stand count) are displayed in Table 5. Year X variety and chemical treatment interactions are displayed in Table 6. Variety X chemical treatment interactions are displayed in Table 7. There were significant differences in yield for all cuttings, alfalfa stem nematode numbers and stand for means averaged over years and varieties. First cutting yields were significantly different averaged over chemical treatments and variety. The chemical treatments had no yield effect on any other cutting, but were statistically significant for total yearly yield.

Several significant observations based on the data include:

- 1) Stand density declined each year regardless of treatment or variety. Initial stand was greater in the susceptible than resistant variety, however by the second year the stand density had equalized in the two varieties. There was no effect of cumulative applications of Furadan 4F at 1.0 lb/acre in maintaining stand density in either variety.
- 2) The number of alfalfa stem nematodes extracted from plant samples is affected by many variables (Griffin 1987) and this type of data can be difficult to interpret. Alfalfa stem nematode numbers and damage symptoms in the field increased from year to year, especially between 1997 and 1998. First cutting yield dropped during that same period, and much of the yield decline can be attributed to stem nematodes. There were significantly more alfalfa stem nematodes extracted from the susceptible than the resistant varieties in the second and third production years. The data does not suggest that Furadan 4F controls alfalfa stem nematodes in that no differences in stem nematode numbers exist between chemical treatments in any year. This may be an artifact of sampling rather than evidence of lack of activity by Furadan 4F against alfalfa stem nematode. Further research is needed to determine the actual effects of Furadan 4F on stem nematodes.
- 3) Furadan 4F 0.5 lb/acre was the highest yielding first cutting chemical treatment in the first two years of the study. Furadan 4F 1.0 lb/acre was the highest yielding first cutting chemical treatment during the third year of the study. This suggests that alfalfa weevil was responsible for loss in first cutting yield during the first two years, and alfalfa stem nematodes and alfalfa weevil were responsible for yield loss in the third year.

- 4) Furadan 4F 0.5 lb/acre applied ~14 days before harvest was superior to the ~28 day before harvest application of Furadan 4F 1.0 lb/acre or Lorsban 4E 0.5 lb/acre ~14 days before harvest in alfalfa weevil control. The application of Furadan 4F 1.0 lb/acre was too early to achieve total alfalfa weevil control, but was equal to Lorsban 4E 0.5 lb/acre ~14 days before harvest, and better than the untreated controls.
- 5) An economic evaluation of the data is presented in Table 4. It indicates that economics of chemical control varies with year and variety. The yield response to early season application of Furadan 4F 1.0 lb/acre in the susceptible variety could not be justified in any year, while there was a positive economic response to the Furadan 4F 0.5 lb/acre in two of the three production years, and near break even in the third year. There were positive economic responses to both rates of Furadan 4F in the resistant variety in the second and third production year, with the greatest difference between the two treatments in the third production year.

DISCUSSION

The results of this study indicate the role of Furadan 4F in management of alfalfa stem nematode is confounded by many factors. One factor which must be considered is there is no direct proof at this time that Furadan 4F actually controlled stem nematodes. The nematode extraction data would suggest that it did not affect nematode numbers, but the yield response noted in years 2 and 3 in the alfalfa stem nematode resistant WL323 could not be ignored. Alfalfa stem nematode resistance in alfalfa is a relative comparison, with resistant varieties classified as those with more than 50% of tested plants showing resistance. When the field was observed for alfalfa stem nematode symptoms in the spring of 1998, damage was obvious from the time spring regrowth occurred, but it was more evident in the Ranger than in the WL323. It is possible the Ranger was affected so severely that the damage was irreversible, while the resistance factor in WL323 was enough to allow a response to the early season Furadan 4F treatment. It is important to note that early season Furadan 4F did not maintain stand over time, even if it was applied each year. It is also important to note that alfalfa stem nematode yield effects were primarily limited to first cutting. White flagging, which is typical of stem nematode infestations, reached its most visible point in second cutting, but did not affect yield. Symptoms which affected yield to the greatest degree were stunting, irregular growth, and swollen nodes, all of which are worse in first cutting alfalfa.

ACKNOWLEDGMENTS

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LITERATURE CITED

Gray, F.A., J.L. Williams, G.D. Griffin and T.E. Wilson. 1994. Distribution in the Western United States on alfalfa and cultivar reaction to mixed populations of *Ditylenchus dipsaci* and *Aphelenchoides ritzemabosi*. J. of Nematology 26(4S):705-719

Griffin, G.D., 1987. Effects of environmental factors and cultural practices on parasitism of alfalfa by *Ditylenchus dispaci*. J. of Nematology 19(3):267-276.

Table 1. Insecticide application dates, materials and rates during three years of experiment.

Treatment	1996			1997			1998		
	Insecticide	Rate	Application Date	Insecticide	Rate	Application Date	Insecticide	Rate	Application Date
		lbs/acre			lbs/acre			lbs/acre	
1	Furadan	1.0	19 Apr	Furadan	1.0	17 Apr	Furadan	1.0	20 Apr
2	Lorsban	0.5	9 May	Furadan	1.0	17 Apr	Furadan	1.0	20 Apr
3	Lorsban	0.5	9 May	Lorsban	0.5	2 May	Furadan	1.0	20 Apr
4	Lorsban	0.5	9 May	Lorsban	0.5	2 May	Lorsban	0.5	4 May
5	Furadan	0.5	9 May	Furadan	0.5	2 May	Furadan	0.5	4 May
6	Untreated			Untreated			Untreated		

Table 2. Harvest dates during the three experiment years.

Cutting	1996	1997	1998
1	22 May	28 May	20 May
2	8 July	3 July	8 July
3	15 August	15 August	18 July
4	1 October	1 October	22 September

Table 3. Economic benefit (dollars) of insecticide application. Assumed a selling price of alfalfa at \$90.00/ton, Furadan 4F 0.5 lb/acre at \$10.00/acre, Furadan 4F 1.0 lb/acre at \$20.00/acre, Lorsban 4E 0.5 lb/acre at \$8.00/acre, and application cost at \$5.00/acre.

	1996		1997		1998	
	Ranger	WL 323	Ranger	WL 323	Ranger	WL 323
Furadan 1.0 lb/acre	-21.40	-23.20	-18.70	7.40	-8.80	32.60
Furadan 0.5 lb/acre	14.70	-2.40	20.10	8.40	-1.50	21.00
Lorsban 0.5 lb/acre	-9.40	-5.80	-11.20	-6.70	-5.80	8.60

Table 4. Alfalfa weevil sweep sample data (combined over chemical treatment or variety) from 1997 and 1998. Analysis of variance was done on transformed data, but actual means are shown. Means within a column grouping above P-values followed by the same letter are not significantly different ($\alpha=0.05$).

Variety	Chemical	Alfalfa weevil per sweep	
		1997	1998
Ranger		2.5	3.6
WL323		2.9	2.8
P-value		0.1783	0.4498
	Furadan 1.0 lb/a, Yr 1,2,3	0.1 a	1.2 bc
	Furadan 1.0 lb/a, Yr 2,3	1.1 ab	1.6 bc
	Furadan 1.0 lb/a, Yr 3	1.9 bc	1.8 bc
	Lorsban 0.5 lb/a, 1.0	2.2 c	2.1 c
	Furadan 0.5	0.1 a	0.1 a
	Untreated	10.8 d	12.6 d
P-value		<0.0001	<0.0001

Table 5. Main plot experimental means. Means within a column grouping above P-values followed by the same letter are not significantly different ($\alpha=0.10$).

Year	Variety	Chemical	Stand	ASN	1st	2nd	3rd	4th	Total
1996			62.3 a	18.4 b	2.20 a	1.87 b	1.78 a	1.35 a	7.20 a
1997			23.2 b	94.4 b	2.24 a	1.99 a	1.64 b	1.02 c	6.89 b
1998			9.5 c	972.7 a	1.59 b	1.76 c	1.54 c	1.10 b	5.99 c
P-value			<0.0001	0.0006	<0.0001	0.0081	0.0001	<0.0001	<0.0001
LSD			3.84	319.4	0.148	0.1038	0.0516	0.0313	0.2331
	Ranger		33.8 a	506.1 a	1.88 a	1.76 a	1.61 a	1.14 a	6.40 a
	WL323		29.6 b	217.6 b	2.14 b	1.98 b	1.70 b	1.17 b	6.99 b
P-value			0.0386	0.0732	0.0040	0.0010	0.0032	0.0836	0.0003
		Furadan 1.0 lb/a, Yr 1,2,3	32.2	383.5	2.02 ab	1.87	1.65	1.17	6.70 ab
		Furadan 1.0 lb/a, Yr 2,3	29.2	390.8	2.05 ab	1.88	1.64	1.16	6.74 a
		Furadan 1.0 lb/a, Yr 3	31.2	409.2	2.08 a	1.89	1.67	1.16	6.80 a
		Lorsban 0.5 lb/a 1.0	32.2	221.5	1.94 bc	1.86	1.62	1.12	6.54 bc
		Furadan 0.5	31.6	385.7	2.12 a	1.90	1.68	1.16	6.88 a
		Untreated	33.7	380.3	1.85 c	1.84	1.66	1.16	6.50 c
P-value			0.6050	0.8966	0.0112	0.5795	0.4160	0.2217	0.0059
LSD					0.1331				0.1858

Table 6. Year X variety and year X chemical treatment interactions. Means within a column grouping above P-values followed by the same letter are not significantly different ($\alpha=0.10$).

Year	Variety	Chemical	Stand	ASN	1st	2nd	3rd	4th	Total
1996	Ranger		68.2 a	19.0	2.06 b	1.69 b	1.74	1.34	6.81 b
1996	WL323		56.5 b	17.8	2.35 a	2.05 a	1.85	1.35	7.59 a
1997	Ranger		23.7 c	157.4	2.26 ab	2.00 a	1.60	1.01	6.87 b
1997	WL323		22.7 c	31.3	2.22 ab	1.98 a	1.68	1.03	6.91 b
1998	Ranger		9.4 d	1341.9	1.33 d	1.60 b	1.51	1.07	5.51 d
1998	WL323		9.7 d	603.6	1.84 c	1.92 a	1.58	1.13	6.47 c
P-value			0.0347	0.1315	0.0229	0.0149	0.4368	0.3804	0.0132
LSD			5.43		0.2097	0.1468			0.3296
1996		Furadan 1.0 lb/a, Yr 1,2,3	65.1	12.5	2.10 cd	1.84	1.76	1.39	7.10
1996		Furadan 1.0 lb/a, Yr 2,3	56.0	36.0	2.10 cd	1.90	1.76	1.34	7.10
1996		Furadan 1.0 lb/a, Yr 3	61.1	15.0	2.21 abcd	1.86	1.79	1.33	7.19
1996		Lorsban 0.5 lb/a 1.0	64.0	11.0	2.30 abc	1.90	1.75	1.31	7.26
1996		Furadan 0.5	60.5	20.0	2.37 a	1.88	1.81	1.35	7.41
1996		Untreated	67.2	16.0	2.14 bcd	1.84	1.82	1.35	7.14
1997		Furadan 1.0 lb/a, Yr 1,2,3	22.8	112.0	2.30 abc	2.00	1.66	1.01	6.96
1997		Furadan 1.0 lb/a, Yr 2,3	22.0	36.0	2.33 ab	1.97	1.65	1.02	6.98
1997		Furadan 1.0 lb/a, Yr 3	23.1	63.2	2.23 abcd	2.00	1.65	1.04	6.92
1997		Lorsban 0.5 lb/a 1.0	22.9	38.5	2.06 d	1.95	1.59	0.98	6.58
1997		Furadan 0.5	25.0	263.5	2.42 a	2.04	1.68	1.02	7.17
1997		Untreated	23.5	53.0	2.10 cd	2.00	1.62	1.03	6.74
1998		Furadan 1.0 lb/a, Yr 1,2,3	8.9	1026.0	1.65 ef	1.77	1.53	1.10	6.05
1998		Furadan 1.0 lb/a, Yr 2,3	9.6	1100.2	1.71 e	1.78	1.52	1.13	6.14
1998		Furadan 1.0 lb/a, Yr 3	9.2	1149.5	1.80 e	1.81	1.58	1.10	6.29
1998		Lorsban 0.5 lb/a 1.0	9.6	615.1	1.47 fg	1.72	1.52	0.07	5.78
1998		Furadan 0.5	9.4	873.5	1.58 ef	1.81	1.56	1.12	6.07
1998		Untreated	10.5	1072.0	1.30 g	1.67	1.56	1.10	5.62
P-value			0.8360	0.9570	0.0785	0.8765	0.9904	0.9234	0.2101
LSD					0.2306				

Table 7. Variety X chemical treatment interactions. Means within a column grouping above P-values followed by the same letter are not significantly different ($\alpha=0.10$).

Variety	Chemical	Stand	ASN	1st	2nd	3rd	4th	Total
Ranger	Furadan 1.0 lb/a, Yr 1,2,3	31.4	700.7	1.82	1.68 d	1.58 c	1.13 def	6.20 f
Ranger	Furadan 1.0 lb/a, Yr 2,3	31.3	445.2	1.88	1.80 c	1.59 c	1.16 bcd	6.44 def
Ranger	Furadan 1.0 lb/a, Yr 3	33.6	500.3	1.92	1.77 c	1.63 bc	1.17 abcd	6.48 de
Ranger	Lorsban 0.5 lb/a 1.0	34.4	357.4	1.83	1.79 c	1.63 bc	1.14 cdef	6.39 ef
Ranger	Furadan 0.5	36.6	653.0	2.08	1.81 c	1.64 bc	1.15 cde	6.68 cd
Ranger	Untreated	35.2	380.0	1.79	1.72 cd	1.59 c	1.10 f	6.20 f
WL323	Furadan 1.0 lb/a, Yr 1,2,3	33.1	66.3	2.21	2.06 a	1.72 a	1.21 ab	7.20 a
WL323	Furadan 1.0 lb/a, Yr 2,3	27.1	336.3	2.22	1.96 ab	1.70 ab	1.16 abcd	7.05 ab
WL323	Furadan 1.0 lb/a, Yr 3	28.8	318.2	2.25	2.01 ab	1.72 a	1.15 cdef	7.12 a
WL323	Lorsban 0.5 lb/a 1.0	29.9	85.7	2.06	1.92 b	1.61 c	1.10 ef	6.69 cd
WL323	Furadan 0.5	26.7	118.3	2.18	2.01 ab	1.72 a	1.18 abc	7.08 bc
WL323	Untreated	32.2	380.7	1.91	1.95 b	1.74 a	1.21 a	6.81
P-value			0.4015	0.3255	0.0620	0.0753	0.0049	0.0514
LSD					0.0959	0.0743	0.0480	0.2628

CONTROL OF ALFALFA INSECTS WITH HAND-APPLIED INSECTICIDES ARDEC, FORT COLLINS, CO, 1999

Hayley Miller, Shawn Walter, Jeff Rudolph, Terri Randolph, Aaron Spriggs,
Hilary Freeman, Lindsay Yerkes, and Frank Peairs

MATERIALS AND METHODS

Treatments were applied on 27 May 1999 with a 'rickshaw-type' CO₂ powered sprayer calibrated to apply 20 gal/acre at 3 mph and 30 psi through six 8004 (LF4) nozzles mounted on a 10 ft boom. Conditions were overcast with winds from the north at 3-5 mph and the temperature was 55°F at the time of treatment. Plots were 10 by 30 ft and arranged in a randomized, complete block design with four replicates. Untreated control and Furadan 4F plots were replicated eight times for a more accurate comparison of treatment effects on yield. Crop height at the time of treatment was 1.5 ft.

Treatments were evaluated by taking 10, 180 degree sweeps per plot with a standard 15 inch diameter insect net one, two, and three weeks after treatment. Precounts were taken two days prior to treatment by taking 100, 180 degree sweeps per replication. Alfalfa weevil larvae, alfalfa weevil adults, and pea aphids were counted. Precounts averaged 15.2 ± 2.0 alfalfa weevil larvae, 0.2 ± 0.1 alfalfa weevil adults, and 34.4 ± 5.5 pea aphids per 10 sweeps. Insect counts transformed by the square root + $\frac{1}{2}$ method were used for analysis of variance and means separated by the Student-Neuman-Keul test ($\alpha=0.05$). Original means are presented in the tables.

Lady beetles (*Coccinellidae*), nabids (*Nabidae*), and spiders (*Arachnida*) were sampled to determine if Steward treatments affected beneficial insects while controlling alfalfa insects. Treatments were evaluated by taking 10, 180 degree sweeps per plot with a standard 15 inch diameter insect net. Beneficial insects were counted one, two, and three weeks after treatment. Beneficial insect counts transformed by the square root + $\frac{1}{2}$ method were used for analysis of variance with mean separation by the Student-Neuman-Keul test ($\alpha=0.05$). Original means are presented in the tables.

Field History

Pests:	Alfalfa weevil, <i>Hypera postica</i> (Gyllenhal) Pea aphid, <i>Acyrtosiphon pisum</i> (Harris)
Cultivar:	Unknown
Plant Stand:	Uniform, few weeds
Irrigation:	Linear move sprinkler with drop nozzles
Crop History:	Alfalfa since 1994
Herbicide:	None
Insecticide:	None prior to experiment
Fertilization:	None
Soil Type:	Sandy Clay, OM 1.8%, pH 8.0
Location:	ARDEC, 4616 North Frontage Road, Fort Collins, CO, 80524 (Block 1030)

RESULTS AND DISCUSSION

Alfalfa weevil pressure was moderate and pea aphid pressure was high. All treatments had fewer alfalfa weevil larvae than the untreated control at one, two, and three weeks after treatment. All treatments had fewer alfalfa weevil adults than the untreated control at three weeks after treatment. No treatment had fewer pea aphids than the untreated control at three weeks after treatment. No phytotoxicity was observed with any treatment. The plots treated with Furadan 4F, 0.50 lb(AI)/acre yielded 6.8% more than the untreated plots but the difference was not significant (two-tailed t-test, $t=1.9570$, $df=14$, $p(t>t_{0.05})=0.0706$). Yield reduction measured since 1995 has averaged 6.8%, with a range of 2.3 to 10.9%.

Beneficial insect counts in Steward treated plots were not significantly different than the untreated control (Tables 4-6). Exceptions are the high rate of Steward at 2 and 3 weeks for coccinellids and spiders, respectively. Too few lacewings (Chrysopidae, 0.22 per 10 sweeps) and syrphids (syrphidae, 0.03 per 10 sweeps) were collected for meaningful statistical analysis.

Table 1. Control of alfalfa weevil larvae, ARDEC, Fort Collins, CO, 1999.

PRODUCT, LB (AI)/ACRE	ALFALFA WEEVIL LARVAE PER 10 SWEEPS \pm SEM ¹		
	1 WEEK	2 WEEKS	3 WEEKS
WARRIOR 1E, 0.02	2.3 \pm 0.5 C	6.5 \pm 2.9 F	1.0 \pm 0.7 D
BAYTHROID 2E, 0.025	5.0 \pm 2.0 C	7.3 \pm 1.9 EF	0.8 \pm 0.5 D
LORSBAN 4E, 0.75	2.5 \pm 1.0 C	7.5 \pm 1.9 EF	10.3 \pm 2.2 C
STEWARD, 0.110	2.0 \pm 1.0 C	11.3 \pm 1.5 DEF	10.0 \pm 1.6 C
FURADAN 4F, 0.50+POUNCE 3.2E, 0.075	4.8 \pm 1.6 C	14.8 \pm 3.8 DEF	11.3 \pm 1.6 C
STEWARD, 0.065	12.5 \pm 3.4 C	26.5 \pm 4.4 CDEF	16.5 \pm 3.2 BC
FURADAN 4F, 0.50+DIMETHOATE 4E, 0.25	10.0 \pm 3.9 C	29.0 \pm 6.4 CDEF	15.5 \pm 1.2 BC
FURADAN 4F, 0.50 ²	16.1 \pm 3.9 C	34.9 \pm 6.0 CDE	20.4 \pm 3.2 BC
STEWARD, 0.025	15.8 \pm 2.8 C	39.0 \pm 4.4 CD	17.8 \pm 5.3 BC
PENNCAP M 2FM, 0.75	61.8 \pm 13.4 B	48.8 \pm 5.2 C	12.8 \pm 2.4 C
FURADAN 4F, 0.25	46.8 \pm 8.1 B	92.5 \pm 17.7 B	30.0 \pm 5.7 B
UNTREATED ²	327.5 \pm 25.8 A	237.0 \pm 33.8 A	58.5 \pm 7.3 A
F Value	81.87	29.52	19.38
p > F	< 0.0001	< 0.0001	< 0.0001

¹ SEM, standard error of the mean. Means in the same column followed by the same letter(s) are not statistically different, SNK ($\alpha=0.05$).

² Treatment repeated (8 replicates rather than 4) for purposes of measuring yield.

Table 2. Control of alfalfa weevil adults, ARDEC, Fort Collins, CO, 1999.

PRODUCT, LB(AI)/ACRE	ALFALFA WEEVIL ADULTS PER 10 SWEEPS \pm SEM ¹		
	1 WEEK	2 WEEKS	3 WEEKS
STEWARD, 0.110	0.0 \pm 0.0	1.3 \pm 0.6 C	3.3 \pm 1.3 B
PENNCAP M 2FM, 0.75	0.3 \pm 0.3	2.5 \pm 0.3 BC	4.0 \pm 0.8 B
STEWARD, 0.065	0.0 \pm 0.0	2.8 \pm 0.8 BC	3.0 \pm 1.1 B
STEWARD, 0.025	0.8 \pm 0.5	3.0 \pm 1.2 BC	4.3 \pm 1.7 B
FURADAN 4F, 0.50 ²	1.0 \pm 0.4	5.4 \pm 1.0 ABC	4.1 \pm 0.8 B
FURADAN 4F, 0.50+POUNCE 3.2E, 0.075	0.3 \pm 0.3	6.3 \pm 0.9 AB	5.5 \pm 1.4 B
LORSBAN 4E, 0.75	0.8 \pm 0.3	6.8 \pm 1.7 AB	7.3 \pm 2.2 B
FURADAN 4F, 0.50+DIMETHOATE 4E, 0.25	0.8 \pm 0.5	6.8 \pm 1.3 AB	4.5 \pm 1.0 B
UNTREATED ²	1.4 \pm 0.4	7.8 \pm 1.5 AB	15.4 \pm 2.0 A
FURADAN 4F, 0.25	1.5 \pm 0.9	7.5 \pm 2.1 AB	4.3 \pm 2.1 B
BAYTHROID 2E, 0.025	1.8 \pm 1.4	9.8 \pm 1.9 A	7.5 \pm 1.5 B
WARRIOR 1E, 0.02	1.5 \pm 0.9	12.3 \pm 3.1 A	5.3 \pm 0.6 B
F Value	0.95	4.41	4.74
p > F	0.5127	< 0.0001	< 0.0001

¹ SEM, standard error of the mean. Means in the same column followed by the same letter(s) are not statistically different, SNK ($\alpha=0.05$).

² Treatment repeated (8 replicates rather than 4) for purposes of measuring yield.

Table 3. Control of pea aphids, ARDEC, Fort Collins, CO, 1999.

PRODUCT, LB(AI)/ACRE	PEA APHIDS PER 10 SWEEPS \pm SEM ¹		
	1 WEEK	2 WEEKS	3 WEEKS
WARRIOR 1E, 0.02	21.3 \pm 3.9 C	93.5 \pm 11.7 E	15.8 \pm 5.1 A
FURADAN 4F, 0.50+POUNCE 3.2E, 0.075	74.3 \pm 7.1 BC	237.5 \pm 26.5 CD	9.8 \pm 3.3 A
PENNCAP M 2FM, 0.75	109.8 \pm 19.1 B	182.0 \pm 27.7 DE	19.8 \pm 2.7 A
LORSBAN 4E, 0.75	122.3 \pm 23.9 B	371.8 \pm 46.8 CD	14.8 \pm 10.1 A
BAYTHROID 2E, 0.025	166.8 \pm 15.5 B	370.0 \pm 52.1 CD	24.3 \pm 11.1 A
FURADAN 4F, 0.50+DIMETHOATE 4E, 0.25	184.5 \pm 31.0 B	321.5 \pm 59.0 CD	13.8 \pm 8.6 A
UNTREATED ²	535.9 \pm 110.8 A	344.1 \pm 59.0 CD	9.8 \pm 1.9 A
FURADAN 4F, 0.50 ²	531.1 \pm 54.0 A	676.4 \pm 108.3 AB	16.0 \pm 3.7 A
FURADAN 4F, 0.25	588.8 \pm 118.1 A	762.8 \pm 134.7 AB	11.8 \pm 3.5 A
STEWARD, 0.025	655.5 \pm 177.7 A	509.8 \pm 124.2 BC	14.3 \pm 3.0 A
STEWARD, 0.110	657.5 \pm 138.9 A	796.8 \pm 161.4 AB	19.3 \pm 11.0 A
STEWARD, 0.065	782.8 \pm 110.7 A	1003.3 \pm 171.7 A	19.5 \pm 7.0 A
F Value	22.06	14.17	4.83
p > F	< 0.0001	< 0.0001	< 0.0001

¹ SEM, standard error of the mean. Means in the same column followed by the same letter(s) are not statistically different, SNK ($\alpha=0.05$).

² Treatment repeated (8 replicates rather than 4) for purposes of measuring yield.

Table 4. Effect of Steward treatments on coccinellids, ARDEC, Fort Collins, CO, 1999.

PRODUCT, LB, (AI)/ACRE	LADY BEETLES PER 10 SWEEPS \pm SEM ¹		
	1 WEEK	2 WEEKS	3 WEEKS
STEWARD, 0.110	1.3 \pm 0.6 A	9.8 \pm 3.3 B	21.8 \pm 3.5 A
STEWARD, 0.025	3.8 \pm 1.3 A	18.5 \pm 3.2 AB	16.5 \pm 3.3 A
STEWARD, 0.065	1.5 \pm 0.6 A	20.5 \pm 4.1 AB	14.8 \pm 4.5 A
UNTREATED ²	3.9 \pm 1.1 A	24.6 \pm 3.9 A	21.9 \pm 2.0 A
F Value	1.13	3.10	1.05
p > F	0.3960	0.0413	0.4368

¹ SEM, standard error of the mean. Means in the same column followed by the same letter(s) are not statistically different, SNK ($\alpha=0.05$).

² Treatment repeated (8 replicates rather than 4) for purposes of yield.

Table 5. Effect of Steward treatments on nabids, ARDEC, Fort Collins, CO, 1999.

PRODUCT, LB, (AI)/ACRE	NABIDS PER 10 SWEEPS \pm SEM ¹		
	1 WEEK	2 WEEKS	3 WEEKS
UNTREATED ²	0.4 \pm 0.3 A	1.6 \pm 0.4 A	5.0 \pm 1.0 A
STEWARD, 0.110	0.5 \pm 0.3 A	0.8 \pm 0.3 A	5.8 \pm 1.4 A
STEWARD, 0.025	0.5 \pm 0.3 A	0.5 \pm 0.5 A	5.3 \pm 1.0 A
STEWARD, 0.065	0.8 \pm 0.5 A	1.3 \pm 0.8 A	6.5 \pm 1.7 A
F Value	1.17	0.88	0.48
p > F	0.3798	0.5388	0.8150

¹ SEM, standard error of the mean. Means in the same column followed by the same letter(s) are not statistically different, SNK ($\alpha=0.05$).

² Treatment repeated (8 replicates rather than 4) for purposes of yield.

Table 6. Effect of Steward treatments on spiders, ARDEC, Fort Collins, CO, 1999.

PRODUCT, LB, (AI)/ACRE	SPIDERS PER 10 SWEEPS \pm SEM ¹		
	1 WEEK	2 WEEKS	3 WEEKS
STEWARD, 0.110	1.0 \pm 0.4 A	2.0 \pm 0.7 A	1.8 \pm 0.9 B
UNTREATED ²	1.9 \pm 0.4 A	2.1 \pm 0.5 A	3.0 \pm 0.4 AB
STEWARD, 0.025	3.0 \pm 1.6 A	2.8 \pm 0.5 A	4.0 \pm 1.1 AB
STEWARD, 0.065	1.3 \pm 0.9 A	2.8 \pm 0.9 A	5.0 \pm 1.1 A
F Value	1.36	0.55	2.21
p > F	0.2990	0.7603	0.1084

¹ SEM, standard error of the mean. Means in the same column followed by the same letter(s) are not statistically different, SNK ($\alpha=0.05$).

² Treatment repeated (8 replicates rather than 4) for purposes of yield.

CONTROL OF ALFALFA INSECTS WITH PROPANE FLAMING AT TWO LOCATIONS IN NORTHEAST COLORADO, 1999

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Lindsay Yerkes, Frank Peairs, Jerry Alldredge, and Ron Jepson

MATERIALS AND METHODS

Propane flaming was performed on 10 March 1999 at the Prior farm near Eaton, CO. Conditions were east to northeast winds at 3 mph and a temperature of 60°F at the time of treatment. Lorsban 4E, 0.75 lb(ai)/acre was applied on 18 May 1999 with a 'rickshaw-type' CO₂ powered sprayer calibrated to apply 20 gal/acre at 3 mph and 30 psi through six 8004 (LF4) nozzles mounted on a 10 ft boom. Conditions were overcast with winds from the north at 3-5 mph and the temperature was 55°F at the time of treatment. Plots were 60 by 300 ft and unreplicated. The remainder of the field was flamed.

Propane flaming was performed at the Murray farm near Brighton, CO on 10 March 1999. Conditions were overcast with winds 4-6 mph with gusts to 12 mph. Baythroid was applied aerially on 15 May 1999. Plots were 60 by 300 ft and unreplicated. The remainder of the field was treated with Baythroid.

Treatments were evaluated by taking 5, 5 second Vortis Suction samples every 10 ft along a transect perpendicular to the plots every two weeks from 1 March through 26 May 1999. Alfalfa weevil larvae, alfalfa weevil adults, and pea aphids were counted. Each location's counts from treated plots were compared to the untreated control using a two-tailed t-test with assumed equal variance ($\alpha=0.05$). Yields were taken at both locations on 3 June 1999 with a Wintersteiger forage harvester which cuts and weighs a 4 ft swath of alfalfa. Swaths were collected at 6 locations within each treatment.

Field History

Pests:	Alfalfa weevil, <i>Hypera postica</i> (Gyllenhal) Pea aphid, <i>Acyrtosiphon pisum</i> (Harris)
Cultivar:	Unknown
Insecticide:	None prior to experiment
Soil Type:	Unknown
Location:	Prior Farm, 36390 Weld County Rd 29, Eaton, CO Murray Farm, 11020 Havana St, Brighton, CO

RESULTS AND DISCUSSION

Yields were higher in the flamed plot than in the untreated control at the Prior Farm (Table 1). Yields were lower than the untreated control in both the flamed and Lorsban plots at the Murray Farm (Table 1). Propane flaming did not reduce the total number of alfalfa weevils or pea aphids at either location (Figures 1 and 2).

Table 1. Effect of propane flaming on alfalfa yield at two locations in northeast Colorado, 1999.

LOCATION	TREATMENT	YIELD ^{1,2}
MURRAY FARM	UNTREATED	1.9
MURRAY FARM	LORSBAN	1.5 (0.0002)
MURRAY FARM	PROPANE FLAMING	1.3 (< 0.0001)
PRIOR FARM	PROPANE FLAMING	2.7 (0.0052)
PRIOR FARM	LORSBAN 4E, 0.75 LB(AI)/ACRE	2.5 (0.2108)
PRIOR FARM	UNTREATED	2.4

¹ Number in parenthesis indicates probability of mean being similar to the untreated control, calculated with a two-tailed t-test with assumed equal variance ($\alpha=0.05$).

² Yield in tons per acre adjusted to average subsample moisture by location.

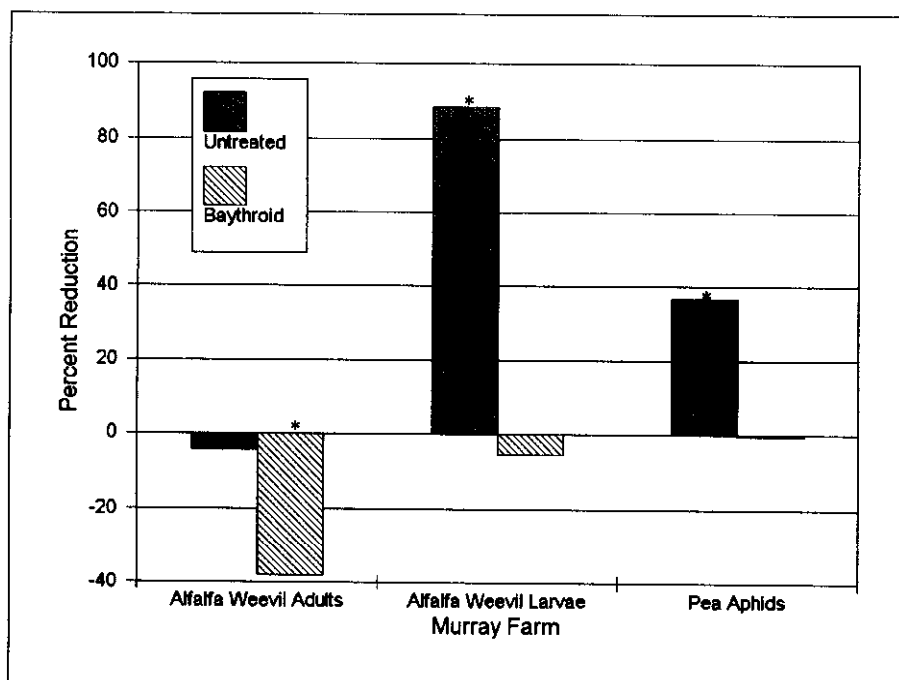


Figure 1. Percent reduction in insect numbers for each treatment as compared with the untreated control, Murray Farm, Brighton, CO, 1999.

* Indicates mean is different from the untreated control, calculated with a two-tailed t-test with assumed equal variance ($\alpha=0.05$).

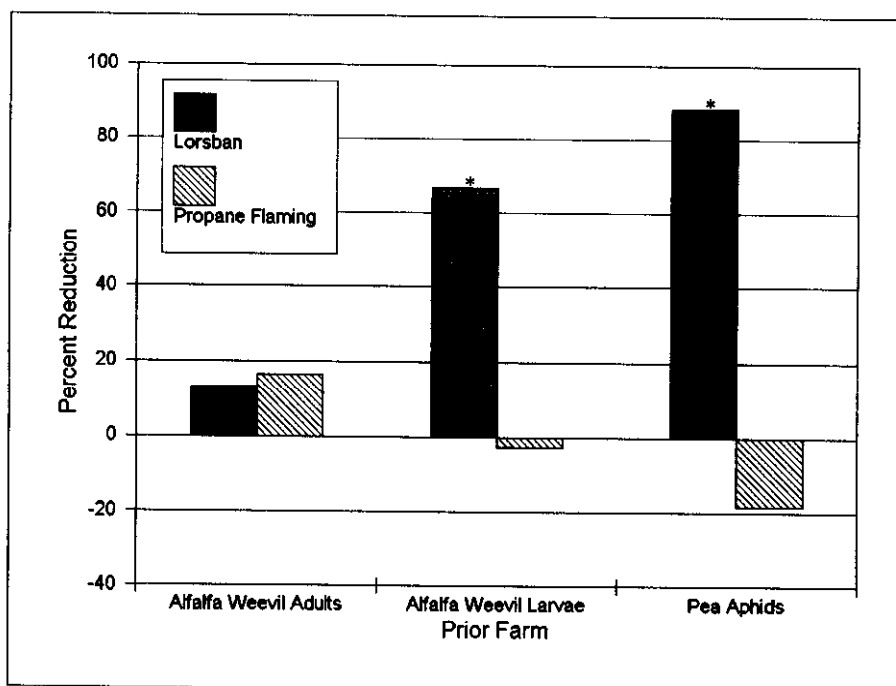


Figure 2. Percent reduction in insect numbers for each treatment as compared with the untreated control, Prior Farm, Eaton, CO, 1999.

* Indicates mean is different from the untreated control, calculated with a two-tailed t-test with assumed equal variance ($\alpha=0.05$).

EVALUATION OF PASTURE GRASSES AT FRUITA, COLORADO 1999

Dr. Calvin H. Pearson

SUMMARY AND RECOMMENDATIONS

A pasture grass species study is being conducted at the Western Colorado Research Center at Fruita in which forage yields of sixteen grass entries have been determined since 1995. This is a progress report for an ongoing study. Total hay yields for 1999 ranged from a high of 5.88 tons/acre for 'Blackwell' switchgrass to a low of 2.54 tons/acre for 'Palaton' reed canarygrass. Total average yield for 1999 was 3.83 tons/acre. High-yielding entries for 1999 were 'Blackwell' switchgrass and 'Fawn' tall fescue. Hay yields totaled across the five years we have collected data in this study ranged from a high of 32.71 tons/acre for 'Blackwell' switchgrass to a low of 16.85 tons/acre for 'Palaton' reed canarygrass. The average for the 5-year total was 22.08 tons/acre. High-yielding entries over this five-year testing period were 'Blackwell' switchgrass and 'Fawn' tall fescue, the same ones as in the individual years. Other entries that have been good forage producers are: 'Newhy' hybrid wheatgrass, 'Regar' meadow brome, 'Potomac' orchardgrass, 'Luna' pubescent wheatgrass, Economy pasture mix, and Premium pasture mix. Forage yields in this study will continue to be collected for several more years. Forage quality, which should also be an important consideration in pasture management, is discussed in another report in this publication.

INTRODUCTION AND OBJECTIVES

Hay, other than alfalfa, was produced on 600,000 acres in Colorado in 1998. Much of the hay produced in Colorado, other than alfalfa, is grass hay. Grass hay in Colorado is produced in pastures, meadows, and other grasslands. Grass hay is an important feed for livestock and many farmers and ranchers depend on pastures, meadows, and other grasslands, not only for hay production, but also for grazing, wildlife habitat, environmental services, crop rotation and cropping system needs, and other reasons.

Pasture grass and forage legume species evaluation and performance studies have been conducted in past years in Colorado (Hoff and Dotzenko 1969, Marquiss 1970, Siemer and Hall 1970, Marquiss and Davis 1971, Siemer and Willhite 1972, Stewart 1973, Rothman and Sprock 1988). Recent pasture grass and forage legume research, other than alfalfa, in the valley areas of Colorado has been limited. The objectives of this ongoing research are to identify grass species and mixtures that produce high yields and high forage quality; to evaluate grass species for stand establishment, weed competition, and stand persistence; and to disseminate the findings of this research to clientele using printed material, electronic media, and oral presentations.

MATERIALS AND METHODS

This study was conducted at the Colorado State University Western Colorado Research Center at Fruita. The experiment is a randomized complete block with four replications. The soil

is a Glenton very fine sandy loam. The elevation at Fruita is 4,510 feet. Average annual precipitation is 8.4 inches and the average frost-free days is 181. The last spring frost occurred on April 17, 1999 and the first fall frost occurred on October 17, 1999, thus the 1999 frost-free days were 183 (28°F base). The plots were planted on April 22, 1994. Fertilizer applications, mostly nitrogen sources, have been applied in split applications in each of the previous years. Fertilizer applications during 1999 were 50 lbs N/acre as ammonium nitrate applied on March 3, 1999 and 55 lbs N/acre as ammonium nitrate applied on August 31, 1999. Plots were harvested with an automated, forage plot harvester that was designed and built at the Fruita Research Center (Pearson and Robinson, 1994). It has been used in our forage plot research for seven years at the Fruita Research Center and it is considered to be a valuable piece of research equipment.

RESULTS AND DISCUSSION

The application of herbicides in this study has been conscientiously avoided in order to determine which of these grass entries are most competitive against invading weeds. Plots were evaluated in spring 2000 for weed infestation. The main weed present in the plots at the time of evaluation was dandelion. The results of that evaluation are shown in Table 1.

Forage yields for the pasture grass species test are shown in Table 2. Hay yields in the first cutting in 1999 ranged from a high of 2.68 tons/acre for 'Fawn' tall fescue to a low of 0.74 tons/acre for 'Palaton' reed canarygrass. The test average for the first cutting in 1999 was 1.71 tons/acre. High-yielding entries were 'Fawn' tall fescue and the Economy pasture mix.

Hay yields in the second cutting in 1999 ranged from a high of 4.39 tons/acre for 'Blackwell' switchgrass to a low of 1.13 tons/acre for 'Oahe' intermediate wheatgrass. The test average for the second cutting in 1999 was 1.69 tons/acre. 'Blackwell' switchgrass, a warm-season grass, had a far superior yield during the warm summer months compared to any of the cool-season grasses. Producers that want to maximize total seasonal hay yields should consider planting separate fields of warm and cool-season grasses.

Hay yields in the third cutting in 1999 ranged from a high of 0.79 tons/acre for 'Fawn' tall fescue to a low of 0.25 tons/acre for 'Latar' orchardgrass. The test average for the third cutting in 1999 was 0.43 tons/acre. High-yielding entries were 'Fawn' tall fescue and the 'Economy' pasture mix, which were also high yielding in the first cutting.

Total hay yields for 1999 ranged from a high of 5.88 tons/acre for 'Blackwell' switchgrass to a low of 2.54 tons/acre for 'Palaton' reed canarygrass. The test average for the total 1999 yield was 3.83 tons/acre. High-yielding entries for 1999 were 'Blackwell' switchgrass and 'Fawn' tall fescue.

Hay yields totaled across the five years we have collected data in this study ranged from a high of 32.71 tons/acre for 'Blackwell' switchgrass to a low of 16.85 tons/acre for 'Palaton' reed canarygrass. The test average for the 5-year total was 22.08 tons/acre. High-yielding entries over this five-year testing period were 'Blackwell' switchgrass and 'Fawn' tall fescue, the same ones as in the individual years. Other entries that have been good forage producers are: 'Newhy' hybrid wheatgrass, 'Regar' meadow brome, 'Potomac' orchardgrass, 'Luna' pubescent wheatgrass, Economy pasture mix, and Premium pasture mix.

This study will continue for several more years. These data will be useful to determine the persistence and productivity of these entries over a long period of time.

ACKNOWLEDGMENTS

Appreciation is expressed to Lot Robinson, Fred Judson, Bob Hammon, and Shane Max (Western Colorado Research Center staff), and Sara Albertson and Daniel Dawson (part-time hourly employees) who assisted with this research. Many companies have provided assistance in various ways (i.e., seed and funding support). These companies include Arkansas Valley Seed Company, Sharp Brothers, Ampac Seed Company, and Peterson Seed Company. The assistance of these companies is gratefully acknowledged

LITERATURE CITED

- Hoff, J.C., and A.D. Dotzenko. 1969. Seed and forage yields of five species of grasses grown under different nitrogen fertilizer levels. Colorado State University Experiment Station Progress Report PR69-31 revised. Fort Collins, Colorado.
- Marquiss, R.W. 1970. Dryland pasture grasses and alfalfa variety tests at Yellow Jacket. Colorado State University Experiment Station Progress Report PR70-28 revised. Fort Collins, Colorado.
- Marquiss, R.W., and Gary Davis. 1971. Recommended dryland pasture grasses and alfalfa for the San Juan Basin. Colorado State University Experiment Station Progress Report PR71-8 revised. Fort Collins, Colorado.
- Rothman, Elmer A., and Harvey A. Sprock. 1988. Horse pastures. Colorado State University Cooperative Extension, Service in Action sheet no. 700.
- Pearson, Calvin H., and Lot Robinson. 1994. Automating a commercial swather for harvesting forage plots. *Agron. J.* 86:1131-1133.
- Siemer, E.G., and T.H. Hall. 1970. Persistence of grass and legume varieties at Gunnison, Colorado. Colorado State University Experiment Station Progress Report PR70:52. Fort Collins, Colorado.
- Siemer, E.G., and F.M. Willhite. 1972. Long-term grass and legume productivity at Gunnison. Colorado State University Experiment Station Progress Report PR72:14. Fort Collins, Colorado.
- Stewart, William G. 1973. Irrigated pastures for Colorado. Cooperative Extension Service, Colorado State University, Fort Collins, Colorado. Bulletin 469A, 28 pps.

Table 1. Pasture grass response to dandelion invasion, March 2000 evaluation.

Pasture Grass	Dandelion infestation rating	Comments
'RS-H' experimental	XX	some dandelion present in all reps
'Newhy' hybrid wheatgrass	XX	some dandelion present in all reps
'Regar' meadow brome	X	a few dandelion present, two reps clean
'Lincoln' smooth brome	X	a few dandelion present, one rep clean
'Manchar' smooth brome	X	a few dandelions present, one rep clean
'Potomac' orchardgrass	-	very weed-free, all reps quite clean
'Latar' orchardgrass	-	quite weed-free, one rep had some dandelion
'Luna' pubescent wheatgrass	XXX	two reps had considerable dandelion present
'Climax' timothy	X	a few dandelion present in all reps
'Bozoisky-Select' Russian wildrye	XX	one rep had a lot of dandelion, other reps had some
'Fawn' tall fescue	-	very weed-free
'Palaton' reed canarygrass	XXX	two reps had a lot of dandelion
'Blackwell' switchgrass	XXX	two reps had a lot of dandelion
'Oahe' intermediate wheatgrass	XXX	two reps had a lot of dandelion
Economy pasture mix	-	weed-free, very clean in all reps
Premium pasture mix	-	weed-free, very few weeds in any of the reps

- none, X = few, XX = moderate amount, XXX = heavy amount of dandelion present.

Table 2. Hay yields¹ of irrigated pasture grasses at the Western Colorado Research Center, Fruita, Colorado 1999.

Pasture Grass	1 st cutting	2 nd cutting	3 rd cutting	Total					
	June 3	Aug 19	Oct 12	1999	1998	1997	1996	1995	5-yr
	----- tons/acre -----								
'RS-H' experimental	1.52	1.32	0.34	3.18	2.62	4.09	3.45	6.89	20.23
'Newhy' hybrid wheatgrass	1.89	1.48	0.41	3.79	3.11	4.69	3.77	7.37	22.73
'Regar' meadow brome	2.08	1.84	0.43	4.36	3.48	5.20	4.26	7.19	24.49
'Lincoln' smooth brome	1.81	1.26	0.32	3.38	2.48	4.56	2.86	5.75	19.03
'Manchar' smooth brome	1.46	1.40	0.27	3.14	2.38	4.90	3.27	5.62	19.31
'Potomac' orchardgrass	1.84	1.50	0.49	3.82	2.63	5.48	3.51	6.13	21.57
'Latar' orchardgrass	1.32	1.72	0.25	3.30	2.48	4.59	3.16	5.91	19.44
'Luna' pubescent wheatgrass	1.74	1.25	0.40	3.39	2.94	4.94	3.92	7.36	22.56
'Climax' timothy	1.84	1.55	0.32	3.72	2.97	4.82	3.39	5.74	20.64
'Bozoisky-Select' Russian wildrye	1.26	1.37	0.48	3.11	2.82	4.19	2.79	4.57	17.48
'Fawn' tall fescue	2.68	1.89	0.79	5.36	5.05	6.92	4.64	8.40	30.37
'Palaton' reed canarygrass	0.74	1.48	0.32	2.54	2.26	4.12	2.70	5.24	16.85
'Blackwell' switchgrass	1.12	4.39	0.36	5.88	6.48	6.21	5.51	8.63	32.71
'Oahe' intermediate wheatgrass	1.60	1.13	0.39	3.12	2.42	3.88	3.45	6.48	19.34
Economy pasture mix ²	2.54	1.90	0.75	5.19	3.81	6.22	3.58	6.21	25.02
Premium pasture mix ³	1.90	1.58	0.49	3.98	2.82	5.48	3.10	6.08	21.45
Average	1.71	1.69	0.43	3.83	3.17	5.02	3.58	6.47	22.08
LSD (0.05)	0.37	0.28	0.13	0.64	0.90	0.98	0.91	1.50	4.29
CV (%)	15.50	11.40	21.10	11.90	19.90	13.80	17.90	16.30	13.80

¹ Yields were calculated on an air-dry basis.

² Economy pasture mix consisted of 35% 'Potomac' orchardgrass, 25% 'Fawn' tall fescue, 20% 'Lincoln' smooth brome, and 20% tetraploid perennial ryegrass.

³ Premium pasture mix consisted of 30% 'Regar' meadowbrome, 25% 'Dawn' orchardgrass, 25% 'Potomac' orchardgrass, and 20% tetraploid perennial ryegrass.

FORAGE QUALITY OF PASTURE GRASSES AT FRUITA, COLORADO

Dr. Calvin H. Pearson

SUMMARY AND RECOMMENDATIONS

Forage quality is an important consideration when determining how to best utilize forages. Forage quality of sixteen grass entries were determined from cuttings in 1996, 1997, and 1999. Generally, in most cuttings in 1996, 'Lincoln' smooth brome, 'Manchar' smooth brome, and 'Climax' timothy had high digestibility and crude protein. 'Oahe' intermediate wheatgrass had high digestibility in all three cuttings in 1996. 'Blackwell' switchgrass had low digestibility and crude protein in most cuttings in 1996. The most consistent response in the 1997 and 1999 cuttings was the poor quality exhibited by 'Blackwell' switchgrass. 'Regar' meadow brome and 'Bozoisky-Select' Russian wildrye also exhibited poor forage quality characteristics in most cuttings. 'Climax' timothy, 'RS-H' experimental, 'Newhy' hybrid wheatgrass, 'Palaton' reed canarygrass, and 'Oahe' intermediate wheatgrass showed a trend toward better forage quality than many other grasses. Other grass entries had variable responses to forage quality characteristics, depending on the cutting. All grass species received the same management and were harvested at the same time in our study. There were significant differences among grass species in the cuttings evaluated, yet there was no consistent responses among many entries across cuttings. This is interpreted to mean these grasses are sufficiently diverse that specific managements are likely needed to obtain optimum forage quality for individual grass entries. Others have recognized this finding, but specific managements for optimum performance of individual grass species have not been thoroughly determined for many grass species.

INTRODUCTION AND OBJECTIVES

The yield of a forage species is an important aspect of forage production. The quality of a forage species is also an important consideration when determining how to best utilize forages. A pasture grass species evaluation study was planted in spring 1994 and forage yields have been obtained for five years beginning in 1995. Forage quality analysis of the sixteen grass entries was determined from samples obtained in 1996, 1997, and 1999. The objective of this research was to determine forage quality periodically of the sixteen grass species as forage yields were collected over the years.

MATERIALS AND METHODS

This study was conducted at the Colorado State University Western Colorado Research Center at Fruita. The experiment is a randomized complete block with four replications. The soil is a Glenton very fine sandy loam. The elevation at Fruita is 4,510 feet. The average annual precipitation is 8.4 inches and the average frost-free days is 181 days. The last spring frost occurred on April 17, 1999 and the first fall frost occurred on October 17, 1999, thus, there were 183 (28°F base) frost-free days in 1999. The plots were planted on April 22, 1994. Fertilizer

applications during 1999 were 50 lbs N/acre as ammonium nitrate applied on March 3, 1999 and 55 lbs N/acre as ammonium nitrate applied on August 31, 1999. Plots have been fertilized regularly each year and furrow-irrigated as needed during each growing season.

As plots were harvested for yield, a subsample was taken for moisture determination. After moistures were determined, samples were oven-dried at 50 °C and then ground in a Wiley Mill. Samples remained frozen until forage quality analysis was conducted. Samples from 1996 were analyzed for digestibility and crude protein by Dr. Joe Brummer at the Mountain Meadow Research Center at Gunnison, Colorado. The samples obtained during 1997 and 1999 were analyzed by Dr. Rod Hintz (1997 samples) and Susan Selman (1999 samples) at the W-L Research laboratory at Evansville, Wisconsin using wet chemistry procedures.

RESULTS AND DISCUSSION

Data for forage yields, digestibility, and crude protein of the sixteen grass entries for the first, second, and third cuttings in 1996 are shown in Tables 1, 2, and 3, respectively. Generally, in most cuttings, 'Lincoln' smooth brome, 'Manchar' smooth brome, and 'Climax' timothy had high digestibility and crude protein. 'Oahe' intermediate wheatgrass had high digestibility in all three cuttings in 1996. 'Blackwell' switchgrass had low digestibility and crude protein in most cuttings in 1996. Other grass species showed mixed responses to forage quality, depending on the cutting.

Data for neutral detergent fiber, acid detergent fiber, lignin, in vitro true digestibility, cell wall digestibility, digestible dry matter, dry matter intake, and relative feed value of sixteen grass entries for the second and third cuttings in 1997 are shown in Tables 4 and 5, respectively. Data for neutral detergent fiber, acid detergent fiber, lignin, in vitro true digestibility, cell wall digestibility, digestible dry matter, dry matter intake, and relative feed value of sixteen grass entries for the first, second, and third cuttings in 1999 are shown in Tables 6, 7, and 8, respectively. Generally speaking, forage quality differed by cutting. Each of the quality characteristics in the two cuttings evaluated in 1997 and the three cuttings evaluated in 1999 had significant differences among the sixteen grass species. However, a consistent response in forage quality among grass entries in the 1997 and 1999 cuttings was not apparent. The most consistent response was the poor quality exhibited by 'Blackwell' switchgrass. 'Regar' meadow brome and 'Bozoisky-Select' Russian wildrye also exhibited poor forage quality characteristics in most cuttings. 'Climax' timothy, 'RS-H' experimental, 'Newhy' hybrid wheatgrass, 'Palaton' reed canarygrass, and 'Oahe' intermediate wheatgrass showed a trend toward better forage quality than many other grasses. Other grass entries had variable responses to forage quality characteristics, depending on the cutting.

All grass species received the same management and were harvested at the same time in our study. There were significant differences among grass species in the cuttings evaluated, yet there was no consistent responses among the entries across cuttings. This is interpreted to mean these grasses are sufficiently different that specific managements are likely needed to obtain optimum forage quality for each grass entry. Other researchers have recognized this finding, but identifying specific managements that are needed for optimum performance of individual grass species is not well known or understood.

ACKNOWLEDGMENTS

Appreciation is expressed to Lot Robinson and Fred Judson (Western Colorado Research Center staff), and Sara Albertson, Daniel Dawson, and Amy Mannel (summer hourly employees) who assisted with this research. Thanks also to the many seed companies who provided seed for planting these plots (Sharp Brothers, Ampac Seed Company, and Peterson Seed Company), particularly to Arkansas Valley Seed Company who has contributed funds for our pasture grass studies. We extend much appreciation to Dr. Rod Hintz and Susan Selman of W-L Research at Evansville, Wisconsin for performing the forage quality analyses. Samples from 1996 were analyzed by Dr. Joe Brummer at the Mountain Meadow Research Center at Gunnison, Colorado. We appreciate Dr. Brummer's assistance.

Table 1. Forage yield, digestibility, and crude protein for the first cutting of sixteen grass entries at the Colorado State University, Western Colorado Research Center at Fruita in 1996.

Pasture grass	Forage yield tons/acre	Digestibility %	Crude protein %
'RS-H' experimental	1.16	77.70	12.40
'Newhy' hybrid wheatgrass	1.63	76.90	11.90
'Regar' meadow brome	1.40	77.70	11.20
'Lincoln' smooth brome	0.99	78.70	12.50
'Manchar' smooth brome	0.94	79.60	12.60
'Potomac' orchardgrass	1.26	75.10	10.60
'Latar' orchardgrass	0.59	77.60	12.70
'Luna' pubescent wheatgrass	1.39	77.70	10.60
'Climax' timothy	0.75	80.30	13.70
'Bozoisky-Select' Russian wildrye	1.00	76.90	10.10
'Fawn' tall fescue	1.58	76.10	11.00
'Palaton' reed canarygrass	0.38	76.30	13.60
'Blackwell' switchgrass	0.52	77.80	11.20
'Oahe' intermediate wheatgrass	1.17	78.80	10.60
Economy pasture mix ¹	0.99	75.40	11.20
Premium pasture mix ²	0.86	77.00	11.00
Average	1.04	77.50	11.70
LSD (0.05)	0.38	1.90	1.20
CV (%)	26.10	1.70	7.00

¹Economy pasture mix consisted of 35% 'Potomac' orchardgrass, 25% 'Fawn' tall fescue, 20% 'Lincoln' smooth brome, and 20% tetraploid perennial ryegrass.

²Premium pasture mix consisted of 30% 'Regar' meadowbrome, 25% 'Dawn' orchardgrass, 25% 'Potomac' orchardgrass, and 20% tetraploid perennial ryegrass.

Table 2. Forage yield, digestibility, and crude protein for the second cutting of sixteen grass entries at the Colorado State University, Western Colorado Research Center at Fruita in 1996.

Pasture grass	Forage yield	Digestibility	Crude protein
	tons/acre	%	%
'RS-H' experimental	0.99	67.8	10.8
'Newhy' hybrid wheatgrass	0.79	69.4	11.1
'Regar' meadow brome	1.14	71.1	10.8
'Lincoln' smooth brome	0.76	69.9	12.0
'Manchar' smooth brome	0.83	72.0	12.2
'Potomac' orchardgrass	0.98	65.2	10.2
'Latar' orchardgrass	1.33	68.7	9.2
'Luna' pubescent wheatgrass	1.32	68.4	9.1
'Climax' timothy	1.76	72.4	9.7
'Bozoisky-Select' Russian wildrye	0.62	71.8	12.1
'Fawn' tall fescue	1.22	69.0	9.2
'Palaton' reed canarygrass	1.02	65.7	10.5
'Blackwell' switchgrass	2.44	63.2	7.2
'Oahe' intermediate wheatgrass	1.38	70.5	9.0
Economy pasture mix ¹	1.14	68.0	9.5
Premium pasture mix ²	1.04	66.8	10.6
Average	1.17	68.7	10.2
LSD (0.05)	0.32	3.1	1.3
CV (%)	19.10	3.2	8.9

¹Economy pasture mix consisted of 35% 'Potomac' orchardgrass, 25% 'Fawn' tall fescue, 20% 'Lincoln' smooth brome, and 20% tetraploid perennial ryegrass.

²Premium pasture mix consisted of 30% 'Regar' meadowbrome, 25% 'Dawn' orchardgrass, 25% 'Potomac' orchardgrass, and 20% tetraploid perennial ryegrass.

Table 3. Forage yield, digestibility, and crude protein for the third cutting of sixteen grass entries at the Colorado State University, Western Colorado Research Center at Fruita in 1996.

Pasture grass	Forage yield	Digestibility	Crude protein
	tons/acre	%	%
'RS-H' experimental	1.22	67.5	9.2
'Newhy' hybrid wheatgrass	1.26	67.7	9.9
'Regar' meadow brome	1.46	67.8	8.2
'Lincoln' smooth brome	1.04	71.1	10.8
'Manchar' smooth brome	1.43	70.0	9.8
'Potomac' orchardgrass	1.10	65.9	9.7
'Latar' orchardgrass	1.13	67.6	8.8
'Luna' pubescent wheatgrass	1.09	67.7	8.9
'Climax' timothy	0.75	72.0	11.2
'Bozoisky-Select' Russian wildrye	0.96	67.1	10.0
'Fawn' tall fescue	1.54	66.4	8.5
'Palaton' reed canarygrass	1.19	66.8	8.7
'Blackwell' switchgrass	2.38	61.7	7.5
'Oahe' intermediate wheatgrass	0.78	70.8	10.1
Economy pasture mix ¹	1.22	68.2	8.8
Premium pasture mix ²	1.05	67.8	9.6
Average	1.22	67.9	9.4
LSD (0.05)	0.34	2.5	1.3
CV (%)	19.30	2.5	10.0

¹Economy pasture mix consisted of 35% 'Potomac' orchardgrass, 25% 'Fawn' tall fescue, 20% 'Lincoln' smooth brome, and 20% tetraploid perennial ryegrass.

²Premium pasture mix consisted of 30% 'Regar' meadowbrome, 25% 'Dawn' orchardgrass, 25% 'Potomac' orchardgrass, and 20% tetraploid perennial ryegrass.

Table 4. Forage quality for the second cutting of sixteen grass entries at the Colorado State University, Western Colorado Research Center at Fruita in 1997.

Pasture grass	Neutral detergent fiber	Acid detergent fiber	Lignin	In vitro true digestibility	ADFD	Digestible dry matter	Dry matter intake	Relative feed value
	%	%	%	%	%	% of dry matter	% of body wt	
'RS-H' experimental	59.0	32.6	3.8	67.7	44.8	63.5	2.04	100.8
'Newhy' hybrid wheatgrass	57.6	31.6	3.9	68.7	45.0	64.3	2.08	103.9
'Regar' meadow brome	64.8	38.3	5.7	69.5	52.8	59.1	1.86	84.9
'Lincoln' smooth brome	57.9	33.2	4.7	76.5	60.2	63.0	2.08	101.4
'Manchar' smooth brome	56.7	32.1	3.5	72.4	50.7	63.8	2.12	104.9
'Potomac' orchardgrass	58.3	32.0	2.3	73.8	54.5	63.9	2.06	102.2
'Latar' orchardgrass	61.9	35.7	2.8	73.8	59.1	61.1	1.94	92.1
'Luna' pubescent wheatgrass	58.6	33.0	4.6	75.4	61.0	63.2	2.05	100.5
'Climax' timothy	60.0	33.8	3.9	68.3	47.1	62.5	2.00	97.0
'Bozoikey-Select' Russian wildrye	61.9	33.8	4.0	71.4	52.8	62.6	1.94	94.2
'Fawn' tall fescue	60.4	32.5	2.9	66.6	48.2	63.6	1.99	97.9
'Palaton' reed canarygrass	62.7	34.0	3.5	64.4	42.5	62.4	1.92	93.0
'Blackwell' switchgrass	70.7	39.2	3.4	58.9	41.8	58.4	1.70	76.8
'Oahe' intermediate wheatgrass	59.0	33.5	3.7	72.3	54.1	63.0	2.04	99.7
Economy pasture mix ¹	59.0	32.5	3.8	71.4	53.5	63.6	2.04	100.3
Premium pasture mix ²	57.7	32.2	2.6	74.4	56.6	63.8	2.08	103.1
Average	60.4	33.7	3.7	70.3	51.5	62.6	2.00	97.0
LSD (0.05)	3.0	2.2	2.1	4.2	7.4	1.7	0.10	7.2
CV (%)	3.5	4.6	39.7	4.2	10.1	1.9	3.40	5.2

¹Economy pasture mix consisted of 35% 'Potomac' orchardgrass, 25% 'Fawn' tall fescue, 20% 'Lincoln' smooth brome, and 20% tetraploid perennial ryegrass.

²Premium pasture mix consisted of 30% 'Regar' meadowbrome, 25% 'Dawn' orchardgrass, 25% 'Potomac' orchardgrass, and 20% tetraploid perennial ryegrass.

Table 5. Forage quality for the third cutting of sixteen grass entries at the Colorado State University, Western Colorado Research Center at Fruita in 1997.

Pasture grass	Neutral detergent fiber	Acid detergent fiber	Lignin	In vitro true digestibility	ADFD	Digestible dry matter	Dry matter intake	Relative feed value
	%	%	%	%	%	% of dry matter	% of body wt	
'RS-H' experimental	58.5	33.1	3.5	71.8	51.9	63.1	2.06	100.5
'Newhy' hybrid wheatgrass	59.0	33.6	5.4	69.0	49.3	62.7	2.04	98.9
'Regar' meadow brome	60.9	37.0	4.9	70.0	50.4	60.1	1.97	91.9
'Lincoln' smooth brome	58.3	33.6	3.8	70.7	50.3	62.7	2.07	100.6
'Manchar' smooth brome	57.3	33.2	3.4	70.4	48.3	63.0	2.10	102.6
'Potomac' orchardgrass	60.7	33.6	3.3	68.1	46.4	62.7	1.98	96.1
'Latar' orchardgrass	59.9	34.2	2.6	72.9	53.9	62.2	2.01	96.7
'Luna' pubescent wheatgrass	57.9	33.8	5.0	72.5	54.8	62.6	2.09	101.4
'Climax' timothy	56.8	31.2	2.8	71.9	51.2	64.6	2.12	106.1
'Bozoiisky-Select' Russian wildrye	63.9	36.6	5.2	64.7	44.3	60.4	1.88	88.1
'Fawn' tall fescue	59.9	31.9	2.1	67.7	47.9	64.1	2.01	99.7
'Palaton' reed canarygrass	52.8	28.3	3.3	67.5	37.1	66.8	2.28	117.9
'Blackwell' switchgrass	60.2	34.6	3.7	65.3	44.6	62.0	2.00	96.2
'Oahe' intermediate wheatgrass	57.8	33.4	3.5	69.4	47.4	62.9	2.08	101.6
Economy pasture mix ¹	58.4	32.4	2.2	70.8	51.0	63.7	2.06	101.4
Premium pasture mix ²	60.4	34.7	3.1	70.8	52.4	61.9	1.99	95.3
Average	58.9	33.4	3.6	69.6	48.8	62.8	2.04	99.7
LSD (0.05)	3.5	2.0	1.9	3.6	6.0	1.6	0.13	8.5
CV (%)	4.2	4.3	37.9	3.6	8.7	1.8	4.35	6.0

¹Economy pasture mix consisted of 35% 'Potomac' orchardgrass, 25% 'Fawn' tall fescue, 20% 'Lincoln' smooth brome, and 20% tetraploid perennial ryegrass.

²Premium pasture mix consisted of 30% 'Regar' meadowbrome, 25% 'Dawn' orchardgrass, 25% 'Potomac' orchardgrass, and 20% tetraploid perennial ryegrass.

Table 6. Forage quality for the first cutting of sixteen grass entries at the Colorado State University, Western Colorado Research Center at Fruita in 1999.

Pasture grass	Neutral detergent fiber	Acid detergent fiber	Lignin	In vitro true digestibility	Cell wall digestibility	Digestible dry matter	Dry matter intake	Relative feed value
	%	%	%	%	%	% of dry matter	% of body wt	
'RS-H' experimental	62.4	31.6	1.4	75.6	61.0	64.3	1.94	97.2
'Newhy' hybrid wheatgrass	67.5	34.7	1.8	71.9	58.5	61.8	1.78	85.3
'Regar' meadow brome	72.6	39.6	2.4	64.5	51.1	58.0	1.65	74.4
'Lincoln' smooth brome	67.2	34.2	2.0	72.8	60.1	62.3	1.80	86.8
'Manchar' smooth brome	68.6	35.3	2.0	67.4	52.4	61.4	1.75	83.2
'Potomac' orchardgrass	70.7	36.3	1.8	63.3	48.2	60.6	1.70	79.9
'Latar' orchardgrass	69.0	33.8	1.4	70.8	58.0	62.6	1.74	84.4
'Luna' pubescent wheatgrass	67.6	34.5	1.6	73.1	60.1	62.0	1.78	85.4
'Climax' timothy	66.3	31.2	1.0	80.5	70.7	64.6	1.81	90.7
'Bozoisky-Select' Russian wildrye	70.0	35.4	2.2	69.2	56.0	61.3	1.72	81.6
'Fawn' tall fescue	67.0	34.4	1.8	65.4	48.4	62.2	1.80	86.4
'Palaton' reed canarygrass	69.1	31.9	0.8	73.6	61.8	64.0	1.74	86.4
'Blackwell' switchgrass	68.6	32.9	1.2	76.9	66.2	63.3	1.75	85.8
'Oahe' intermediate wheatgrass	67.1	33.6	1.4	75.7	64.0	62.7	1.79	87.1
Economy pasture mix ¹	67.0	34.4	1.4	68.4	52.9	62.1	1.80	86.4
Premium pasture mix ²	71.4	37.7	2.4	65.4	51.6	59.5	1.68	77.6
Average	68.2	34.4	1.7	70.9	57.6	62.0	1.76	84.9
LSD (0.05)	3.8	3.2	0.8	6.2	8.1	2.5	0.11	8.5
CV (%)	3.9	6.6	34.8	6.2	9.8	2.8	4.50	7.0

¹Economy pasture mix consisted of 35% 'Potomac' orchardgrass, 25% 'Fawn' tall fescue, 20% 'Lincoln' smooth brome, and 20% tetraploid perennial ryegrass.

²Premium pasture mix consisted of 30% 'Regar' meadowbrome, 25% 'Dawn' orchardgrass, 25% 'Potomac' orchardgrass, and 20% tetraploid perennial ryegrass.

Table 7. Forage quality for the second cutting of sixteen grass entries at the Colorado State University, Western Colorado Research Center at Fruita in 1999.

Pasture grass	Neutral detergent fiber	Acid detergent fiber	Lignin	In vitro true digestibility	Cell wall digestibility	Digestible dry matter	Dry matter intake	Relative feed value
	%	%	%	%	%	% of dry matter	% of body wt	
'RS-H' experimental	61.2	30.2	1.9	78.6	65.1	65.4	1.97	99.6
'Newhy' hybrid wheatgrass	60.7	30.1	2.0	79.6	66.4	65.5	1.98	100.6
'Regar' meadow brome	65.9	35.4	1.5	78.1	66.8	61.4	1.82	86.6
'Lincoln' smooth brome	66.9	34.2	2.7	74.0	62.0	62.3	1.81	87.5
'Manchar' smooth brome	61.4	30.1	1.4	80.4	68.1	65.4	1.96	99.1
'Potomac' orchardgrass	64.2	32.8	1.6	78.1	66.0	63.4	1.89	92.6
'Latar' orchardgrass	65.9	33.3	1.0	78.4	67.3	63.0	1.83	89.1
'Luna' pubescent wheatgrass	65.4	33.0	1.6	76.5	64.3	63.2	1.84	90.3
'Climax' timothy	64.2	31.1	1.7	80.7	70.0	64.7	1.87	94.2
'Bozoisky-Select' Russian wildrye	65.7	32.5	2.6	74.8	61.6	63.5	1.83	90.1
'Fawn' tall fescue	65.4	29.7	0.8	76.5	64.1	65.8	1.84	93.6
'Palaton' reed canarygrass	60.6	28.2	1.9	73.3	56.8	66.9	2.00	104.1
'Blackwell' switchgrass	73.7	40.3	3.7	61.9	48.6	57.5	1.63	73.0
'Oahe' intermediate wheatgrass	65.3	32.2	1.7	78.6	67.4	63.9	1.84	91.3
Economy pasture mix ¹	65.8	31.4	1.5	74.6	61.6	64.4	1.83	91.7
Premium pasture mix ²	67.0	33.4	2.0	75.6	63.5	62.9	1.79	87.4
Average	64.9	32.4	1.8	76.2	63.7	63.7	1.86	91.9
LSD (0.05)	5.6	3.0	0.9	7.6	8.6	2.4	0.17	11.1
CV (%)	6.1	6.6	35.8	7.0	9.5	2.6	6.50	8.5

¹Economy pasture mix consisted of 35% 'Potomac' orchardgrass, 25% 'Fawn' tall fescue, 20% 'Lincoln' smooth brome, and 20% tetraploid perennial ryegrass.

²Premium pasture mix consisted of 30% 'Regar' meadowbrome, 25% 'Dawn' orchardgrass, 25% 'Potomac' orchardgrass, and 20% tetraploid perennial ryegrass.

Table 8. Forage quality for the third cutting of sixteen grass entries at the Colorado State University, Western Colorado Research Center at Fruita in 1999.

Pasture grass	Neutral detergent fiber	Acid detergent fiber	Lignin	In vitro true digestibility	Cell wall digestibility	Digestible dry matter	Dry matter intake	Relative feed value
	%	%	%	%	%	% of dry matter	% of body wt	
'RS-H' experimental	49.0	21.1	1.1	89.9	79.2	72.4	2.46	138.0
'Newhy' hybrid wheatgrass	48.8	21.1	0.9	90.2	79.9	72.5	2.47	138.6
'Regar' meadow brome	52.0	24.6	1.1	89.9	80.6	69.7	2.31	124.9
'Lincoln' smooth brome	49.8	21.3	1.0	90.2	80.2	72.3	2.42	135.2
'Manchar' smooth brome	49.2	21.0	0.8	90.7	81.1	72.6	2.45	137.7
'Potomac' orchardgrass	51.6	21.4	0.9	89.4	79.4	72.2	2.33	130.4
'Latar' orchardgrass	50.2	21.1	0.6	91.0	82.0	72.5	2.40	134.7
'Luna' pubescent wheatgrass	49.7	21.9	1.1	90.7	81.3	71.9	2.42	134.8
'Climax' timothy	50.9	20.3	0.5	91.2	82.7	73.1	2.36	133.7
'Bozoisky-Select' Russian wildrye	53.4	23.2	0.9	89.4	80.3	70.8	2.25	123.8
'Fawn' tall fescue	52.3	22.8	0.7	87.9	76.7	71.2	2.30	126.6
'Palaton' reed canarygrass	48.4	19.6	0.8	90.3	79.9	73.7	2.48	141.6
'Blackwell' switchgrass	53.9	23.9	0.8	86.2	74.4	70.3	2.23	121.5
'Oahe' intermediate wheatgrass	47.4	22.0	1.0	91.0	80.8	71.8	2.54	141.6
Economy pasture mix ¹	52.5	22.4	0.3	89.7	80.4	71.4	2.29	126.6
Premium pasture mix ²	51.2	21.9	0.7	90.4	81.2	71.8	2.34	130.5
Average	50.6	21.8	0.8	89.9	80.0	71.9	2.38	132.5
LSD (0.05)	2.6	1.1	0.6	1.4	2.7	0.9	0.13	8.0
CV (%)	3.6	3.7	52.2	1.1	2.4	0.9	3.70	4.3

¹Economy pasture mix consisted of 35% 'Potomac' orchardgrass, 25% 'Fawn' tall fescue, 20% 'Lincoln' smooth brome, and 20% tetraploid perennial ryegrass.

²Premium pasture mix consisted of 30% 'Regar' meadowbrome, 25% 'Dawn' orchardgrass, 25% 'Potomac' orchardgrass, and 20% tetraploid perennial ryegrass.

EVALUATION OF PASTURE GRASSES, FORAGE LEGUMES, AND MIXTURES AT MEEKER, COLORADO 1999

Dr. Calvin H. Pearson

SUMMARY AND RECOMMENDATIONS

Fifty single and mixed grass and forage legume species are being evaluated for forage yield at Meeker. This is a progress report for an ongoing study. The study was planted in the fall of 1996. Yield data for 1999 reflect forage species performance after three years of production. Averaged across all 50 entries, forage yield in the first cutting in 1999 was 2.07 tons/acre. Yields in the first cutting in 1999 ranged from a high of 3.2 tons/acre to a low of 0.02 tons/acre. Averaged across all entries, forage yield in the second cutting in 1999 was 1.13 tons/acre. Yields in the second cutting ranged from a high of 2.28 tons/acre to a low of 0.09 tons/acre. The 3-year total yield, averaged across all entries, was 7.81 tons/acre. Seven entries were high yielding for the 3-year total. They were smooth brome + orchardgrass + intermediate wheatgrass + alfalfa at 12.36 tons/acre, smooth brome + orchardgrass + meadow brome + alfalfa at 12.13 tons/acre, 'Newhy' + alfalfa in alternate seed rows at 11.67 tons/acre, smooth brome + alfalfa planted as a seed mixture at 12.09 tons/acre, smooth brome + alfalfa planted in alternate seed rows at 12.05 tons/acre, 'AV120' alfalfa + 'Norcen' birdsfoot trefoil at 10.89 tons/acre, and 'AV120' alfalfa at 11.12 tons/acre. This study will continue for several more years to determine forage yields over an extended period of time.

INTRODUCTION AND OBJECTIVES

Grasses and forage legumes are produced on more land in western Colorado than any other single crop. Both irrigated and non-irrigated pastures and meadows, and ranges are found throughout the mountain and valley areas of western Colorado. These crop and rangelands produce forage for grazing animals and hay for livestock. These forages are essential to support the large livestock industry of western Colorado.

Pastures, meadows, and ranges in western Colorado contain a diversity of forage plants, some of which are native while others are introduced species. Proper selection and management of grass and legume species for pastures, meadows, and ranges will affect the productivity of these forage lands during establishment and throughout the life of the field or range. The objectives of this research were to: 1) Identify grass and forage legume species and mixtures that produce high yields and high quality, 2) Determine the performance of cool and warm season grasses when planted in mixtures or in alternate seed rows, 3) Determine the performance of forage legumes when planted in mixtures or in alternate seed rows with a grass species, and 4) Assess grass and forage legume species for stand establishment, weed competition, and stand persistence. Fifty entries of single grass and forage legume species and mixed grass and legume species were evaluated at Meeker, Colorado during 1999.

MATERIALS AND METHODS

This study was conducted at the Upper Colorado Environmental Plant Materials Center at Meeker, Colorado. The experimental design is a randomized complete block with four replications. Plot size is 10 feet wide by 15 feet long. The elevation at Meeker is 6,240 feet. The mean maximum annual temperature is 60.4 °F and the mean minimum annual temperature is 26.8 °F.

The experiment was planted on August 9, 1996. Most entries established well. Warm season grasses did not establish with the fall planting. All plots were replanted on June 25, 1997. This was done to thicken the stand in some plots and to attempt to establish the warm season grasses. It was easier to replant all plots rather than selected ones.

Fertilizer applications in 1997 were 50 lbs N/acre as ammonium nitrate on May 14; 73 lbs N/acre and 104 lbs P₂O₅/acre as 11-52-0 and ammonium nitrate on August 25. Fertilizer applications in 1998 were 46 lbs N/acre as ammonium nitrate on July 7. Fertilizer applications in 1999 were 46 lbs N/acre as ammonium nitrate on July 6; 15 lbs N/acre and 70 lbs P₂O₅/acre as 11-52-0 on September 15. No herbicides have been applied to the plots.

The experimental area has been sprinkler irrigated each year generally four times or less - once or twice before the first cutting and once or twice before the second cutting. Typically, plots have not been irrigated after the second cutting for the remainder of the year.

Plots were harvested with a John Deere 2280 commercial swather that was equipped with a weigh bin and an electronic weighing system. The weigh bin was fitted underneath the swather to catch the forage as it was discharged from the crimper. This automated, forage plot harvesting system has been in use for several years and has performed extremely well. During harvest, a small forage sample was obtained from each plot and used for moisture determination.

RESULTS AND DISCUSSION

Yield data for 1999 reflect forage species performance after three years of production. Averaged across all 50 entries, forage yield in the first cutting in 1999 was 2.07 tons/acre. Yields in the first cutting ranged from a high of 3.2 tons/acre to a low of 0.02 tons/acre. Fourteen entries had forage yields in the first cutting equal to or greater than 2.75 tons/acre. Averaged across all entries, forage yield in the second cutting in 1999 was 1.13 tons/acre. Yields in the second cutting ranged from a high of 2.28 tons/acre to a low of 0.09 tons/acre. Eight entries had forage yields in the second cutting that were greater than 2 tons/acre.

Entries 37, 48, 33, 46, and 22 had high yields in both the first and the second cuttings. Average total 1999 forage yield was 3.20 tons/acre. Eight entries (48, 37, 33, 46, 22, 19, 41, and 26) were high yielding for the 1999 total yield.

Average total 1998 forage yield was 2.89 tons/acre. Eight entries (33, 37, 41, 46, 19, 26, 48, and 22) were high yielding for the 1998 total yield. Average total 1997 forage yield was 1.72 tons/acre. Fifteen entries (21, 46, 9, 48, 8, 50, 17, 47, 41, 7, 1, 49, 43, 20, 37) were high yielding for the 1997 total yield. High total yields for 1997 may be an indicator of how quickly an entry becomes established and how productive it is during establishment.

The 3-year average total yield was 7.81 tons/acre. Seven entries (48, 46, 37, 33, 41, 19, and 26) were high yielding for the 3-year total. All of these entries included alfalfa either alone or as

a mixture with other species. The only other entry to include alfalfa that was not in the high yielding category was Entry 22 ('Spredor II' alfalfa) and it ranked 8 out of the 50 entries for yield.

A few observations about some of the entries at Meeker are worth mentioning. The forage chicory stand is thinning rapidly. Cicer milkvetch is not very prevalent in plots. 'San Luis' slender wheatgrass growth is poor. Plots with 'San Luis' are quite weedy. Four entries were planted in 1999 ('Dacotah' switchgrass, 'Bison' big bluestem, 'Liso' smooth brome, and 'Garnet' mountain brome) to replace other entries that did not perform well at Meeker. These new plots had some weeds and, although the new plantings had good stands, they were not expected to be very productive during the establishment year.

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Table 1. Forage yields of single and mixed species of pasture grasses and forage legumes at Meeker, Colorado, 1999.

Entry	Cut 1 Sept 9	Cut 2 July 1	Total			3-Yr	Air-dry fraction
			1999	1998	1997		
			tons/acre ¹				
1. Smooth brome 'Liso'	0.02	0.19	0.21	0.81	2.27	3.28	42.6
2. Creeping foxtail 'Garrison'	1.46	0.47	1.93	1.56	0.82	4.31	46.2
3. Reed canarygrass 'Venture'	1.26	0.82	2.08	1.92	1.04	5.04	43.1
4. Tall fescue 'Advance'	1.51	0.85	2.36	2.38	1.76	6.50	40.7
5. Orchardgrass 'Duke'	1.57	1.16	2.73	2.24	2.00	6.96	44.9
6. Orchardgrass 'Tekapo'	1.33	0.93	2.26	1.62	1.45	5.33	44.4
7. Meadowbrome 'Fleet'	2.51	0.93	3.47	2.91	2.27	8.65	43.4
8. Intermediate wheatgrass 'Oahe'	2.53	0.56	3.08	3.09	2.66	8.83	42.0
9. Pubescent wheatgrass 'Luna'	2.69	0.70	3.39	3.15	2.77	9.31	43.1
10. Slender wheatgrass 'San Luis'	1.42	0.58	1.99	1.84	1.37	5.20	44.8
11. Hybrid wheatgrass 'Newhy'	2.19	1.42	3.60	2.85	1.87	8.32	44.9
12. Beardless wildrye 'Shoshone'	1.44	0.65	2.09	1.42	0.49	3.99	42.4
13. Big bluestem 'Bison'	0.02	0.12	0.14	1.36	0.20	1.70	40.1
14. Switchgrass 'Dacotah'	0.02	0.20	0.22	1.01	0.21	1.43	40.8
15. Timothy 'Climax'	1.49	0.41	1.90	1.85	1.39	5.14	42.1
16. Tall fescue 'Enforcer'	2.11	0.83	2.94	2.57	1.67	7.18	41.9
17. Intermediate wheatgrass 'Rush'	2.37	0.85	3.21	3.12	2.58	8.91	40.5
18. Mountain brome 'Garnet'	0.02	0.09	0.11	1.99	0.63	2.73	40.2
19. Alfalfa 'AV120'	2.51	2.22	4.72	4.39	2.01	11.12	36.8
20. Forage chicory 'LaCerta'	1.23	0.99	2.21	2.00	2.22	6.42	29.6
21. Mountain brome 'Bromar'	1.43	0.64	2.06	1.72	2.78	6.56	42.1
22. Alfalfa 'Spredor III'	2.79	2.01	4.81	4.06	1.89	10.75	36.9
23. Birdsfoot trefoil 'ARS2620'	2.75	1.20	3.95	3.14	0.34	7.43	34.8
24. Ladino clover 'Will'	0.81	0.53	1.34	1.44	0.38	3.16	40.7
25. Redtop	1.38	0.65	2.03	1.45	0.98	4.45	43.6
26. Alfalfa 'AV120' + Birdsfoot trefoil 'Norcen'	2.51	2.15	4.66	4.35	1.88	10.89	36.7
27. Cicer milkvetch 'Windsor'	2.38	1.77	4.15	3.74	0.95	8.84	37.4
28. Sainfoin 'Remont'	3.20	1.31	4.50	3.31	0.87	8.68	38.7
29. Switchgrass + 'Newhy' (alternate seed rows)	1.96	0.85	2.81	2.58	1.50	6.89	44.4
30. Switchgrass + tall fescue (alternate seed row)	1.94	0.86	2.79	2.85	1.59	7.23	42.1
31. Switchgrass + 'Newhy' (mixed)	2.10	0.68	2.78	2.62	2.07	7.47	44.3

Table 1 (continued). Forage yields of single and mixed species of pasture grasses and forage legumes at Meeker, Colorado 1999 .

Entry	Cut 1 Sept 9	Cut 2 July 1	Total			3-Yr	Air-dry fraction
			1999	1998	1997		
			-----tons/acre ¹ -----				
32. Switchgrass + tall fescue (mixed)	1.72	0.75	2.47	2.52	1.63	6.62	43.4
33. Smooth brome + alfalfa (alternate seed rows)	2.99	2.25	5.24	4.75	2.05	12.05	42.3
34. Smooth brome + birdsfoot trefoil (alternate seed rows)	2.90	1.30	4.20	3.77	1.82	9.78	42.2
35. Smooth brome + cicer milkvetch (alternate seed rows)	2.67	1.88	4.55	3.76	1.93	10.23	40.9
36. Smooth brome + sainfoin (alternate seed rows)	2.84	1.27	4.11	3.64	1.44	9.18	41.8
37. Smooth brome + alfalfa (mixed)	3.08	2.18	5.26	4.69	2.15	12.09	42.7
38. Smooth brome + birdsfoot trefoil (mixed)	2.49	1.19	3.68	3.22	1.81	8.70	42.7
39. Smooth brome + cicer milkvetch (mixed)	2.87	1.74	4.61	3.80	1.84	10.25	42.5
40. Smooth brome + sainfoin (mixed)	3.15	1.39	4.53	3.38	1.50	9.40	42.3
41. 'Newhy' + alfalfa (alternate seed rows)	2.50	2.18	4.68	4.59	2.40	11.67	40.2
42. 'Newhy' + birdsfoot trefoil (alternate seed rows)	2.75	1.41	4.16	3.55	1.67	9.38	40.8
43. 'Newhy' + cicer milkvetch (alternate seed rows)	2.56	1.70	4.26	3.66	2.23	10.15	42.0
44. 'Newhy' + sainfoin (alternate seed rows)	2.91	1.13	4.03	3.25	1.78	9.05	42.0
45. Smooth brome + orchardgrass + meadow brome	1.95	1.29	3.24	2.63	1.88	7.75	45.1
46. Smooth brome + orchardgrass + meadow brome + alfalfa	2.83	2.03	4.86	4.51	2.77	12.13	41.0
47. Smooth brome + orchardgrass + intermediate wheatgrass	2.39	1.14	3.53	3.01	2.51	9.04	42.1
48. Smooth brome + orchardgrass + intermediate wheatgrass + alfalfa	3.00	2.28	5.27	4.33	2.76	12.36	38.3
49. Smooth brome + orchardgrass + meadow brome + creeping foxtail	1.93	1.14	3.07	2.90	2.26	8.22	44.0
50. Smooth brome 'Bounty'	2.98	0.60	3.57	3.51	2.63	9.71	44.2
Average	2.07	1.13	3.20	2.89	1.72	7.81	0.42
CV (%)	15.50	23.00	14.40	17.50	27.40	14.40	5.20
LSD (0.05)	0.45	0.36	0.64	0.71	0.66	1.58	3.02

In entries 29-49, we used 'Blackwell' switchgrass, 'Fawn' tall fescue, 'Manchar' smooth brome, 'AV120' alfalfa, 'Norcen' birdsfoot trefoil, 'Remont' sainfoin, 'Windsor' cicer milkvetch, 'Tekapo' orchardgrass, 'Regar' meadow brome, 'Oahe' intermediate wheatgrass, and 'Garrison' creeping foxtail.

¹ Yields were calculated on an air-dry basis.

[†] 'Liso' smooth brome, 'Dacotah' switchgrass, 'Bison' big bluestem, and 'Garnet' mountain brome were planted July 6, 1999 to replace 'Matua' bromegrass, 'Blackwell' switchgrass, 'Praireland' altai wildrye, and 'Kaw' big bluestem, respectively, that did not establish at Meeker.

EVALUATION OF PASTURE GRASSES, FORAGE LEGUMES, AND MIXTURES AT HOTCHKISS, COLORADO 1999

Dr. Calvin H. Pearson and Dr. Alvan G. Gaus

SUMMARY AND RECOMMENDATIONS

Fifty single and mixed grass and forage legume species are being evaluated for forage yield at Hotchkiss. The study was planted in spring 1998 and is similar to the study being conducted at Meeker. This is a progress report for an ongoing study. The data for 1999 are for the first full year of production. Averaged across all 50 entries, forage yields in the first cutting, second cutting, and the 1999 total yield were 2.28, 2.16, and 5.68 tons/acre, respectively. Eight entries were high yielding in the 1999 total yield. Averaged across all 50 entries, the 2-year total yield was 6.92 tons/acre. Eight entries were high yielding in the 2-year total yield. They were 'AV120' alfalfa, 'LaCerta' forage chicory, 'AV120' alfalfa + 'Norcen' birdsfoot trefoil, smooth brome + alfalfa in alternate seed rows, smooth brome + alfalfa planted as a mixture, 'Newhy' + alfalfa in alternate seed rows, and smooth brome + orchardgrass + meadow brome + alfalfa. These were the same eight entries that had high yields in the 1999 total yield, although the ranking was slightly different. This research will continue for several more years to determine the productivity of these entries under long term production.

INTRODUCTION AND OBJECTIVES

Grasses and forage legumes are produced on more land in western Colorado than any other crop. Both irrigated and non-irrigated pastures and meadows, and ranges are found throughout the mountain and valley areas of western Colorado. These crop and rangelands produce forage for grazing animals or hay that is fed later. These forages are essential to support the large livestock industry in western Colorado. Pastures, meadows, and ranges in western Colorado contain a diversity of forage plants, some of which are native while others are introduced species.

Proper selection and management of grass and legume species for pastures, meadows, and ranges will affect the productivity of these forage lands during establishment and throughout the life of the field or range. The objectives of this research were to: 1) Identify grass and forage legume species and mixtures that produce high yields and high quality, 2) Determine the performance of cool and warm season grasses when planted in mixtures or in alternate seed rows, 3) Determine the performance of forage legumes when planted in mixtures or in alternate seed rows with a grass species, and 4) Assess grass and forage legume species for stand establishment, weed competition, and stand persistence. Fifty entries of single grass and forage legume species and mixed grass and legume species were evaluated at the Rogers Mesa Research Center at Hotchkiss, Colorado during 1999.

MATERIALS AND METHODS

This study was conducted at the Colorado State University Western Colorado Research Center at Rogers Mesa. The elevation at Hotchkiss is 5,800 feet. The experiment was a randomized complete block with four replications. Plot size is 10 feet wide by 15 feet long. Plots were planted on April 28, 1998. The plot area was flailed on July 16, 1998 to control weeds, particularly sweet clover and annual weeds. Fertilizer was applied during 1998 on July 21 and was 38.8 lbs N/acre and 44.8 lbs P_2O_5 /acre. Fertilizer applied in 1999 was 16 lbs P_2O_5 /acre and 42 lbs N/acre on April 29 using a combination of 18-46-0 and ammonium nitrate and 74 lbs N/acre as ammonium nitrate on June 26. No herbicides have been applied. The experimental area is furrow-irrigated.

Plots were harvested with a John Deere 2280 commercial swather that was equipped with a weigh bin and an electronic weighing system. The weigh bin was fitted underneath the swather to catch the forage as it was discharged from the crimper. This automated, forage plot harvesting system has been in use for several years and has performed extremely well. During harvest, a small forage sample was obtained from each plot and used for moisture determination.

RESULTS AND DISCUSSION

Plots were planted in spring 1998 and one cutting was obtained in 1998. The data for the 1998 cutting reflect stand establishment and productivity of a new stand (Table 1). Entries with high yields established more readily and were more productive than those entries with low yields. Averaged across all 50 entries, forage yields in the 1998 cutting were 1.24 tons/acre. Eight entries were high yielding in 1998. They were 'AV120' alfalfa, 'LaCerta' forage chicory, 'AV120' alfalfa + 'Norcen' birdsfoot trefoil, smooth brome + alfalfa in alternate seed rows, smooth brome + alfalfa planted as a mixture, 'Newhy' + alfalfa in alternate seed rows, smooth brome + orchardgrass + meadow brome + alfalfa, and smooth brome, orchardgrass + intermediate wheatgrass + alfalfa.

The data for 1999 are for the first full year of production in which two cuttings were obtained (Table 1). Averaged across all 50 entries, forage yields in the first cutting were 2.28 tons/acre. Three single specie grass entries were the highest-yielding entries in the first cutting in 1999. They were 'Fleet' meadowbrome (3.01 tons/acre), 'Oahe' intermediate wheatgrass (3.08 tons/acre), and 'Luna' pubescent wheatgrass (3.46 tons/acre).

Forage yields in the second cutting averaged 2.16 tons/acre. Ten entries were high yielding in the 1999 second cutting. These entries were: 'Matua' brome grass, 'Blackwell' switchgrass, 'AV120' alfalfa, 'LaCerta' forage chicory, 'Spredor III' alfalfa, 'AV120' alfalfa + 'Norcen' birdsfoot trefoil, smooth brome + alfalfa in alternate seed rows, smooth brome + alfalfa planted as a mixture, 'Newhy' + alfalfa in alternate seed rows, and smooth brome + orchardgrass + meadow brome + alfalfa.

Averaged across all 50 entries, 1999 total forage yields were 5.68 tons/acre. Eight entries were high yielding in the 1999 total yield. They were 'AV120' alfalfa, 'LaCerta' forage chicory, 'AV120' alfalfa + 'Norcen' birdsfoot trefoil, smooth brome + alfalfa in alternate seed rows, smooth brome + alfalfa planted as a mixture, 'Newhy' + alfalfa in alternate seed rows, and smooth brome + orchardgrass + meadow brome + alfalfa. Entries with low yields were

obviously not as productive as those entries with high yields, but often entries with low yields were a combination of seeded species and weeds. All the entries had good stands and low forage yields were the result of factors other than poor stand establishment.

The 2-year total yield averaged 6.92 tons/acre. Eight entries were high yielding in the 2-year total yield. They were 'AV120' alfalfa, 'LaCerta' forage chicory, 'AV120' alfalfa + 'Norcen' birdsfoot trefoil, smooth brome + alfalfa in alternate seed rows, smooth brome + alfalfa planted as a mixture, 'Newhy' + alfalfa in alternate seed rows, and smooth brome + orchardgrass + meadow brome + alfalfa. These were the same entries that were high yielding for the 1999 total yield, although the ranking was slightly different.

ACKNOWLEDGMENTS

Appreciation is expressed to Lot Robinson, Fred Judson, Brian Braddy, George Osborn, and Shane Max (Western Colorado Research Center staff), and Sara Albertson and Daniel Dawson (part-time hourly employees) who assisted with this research. Many companies have provided assistance in various ways (i.e., seed and funding support). These companies include Arkansas Valley Seed Company, Sharp Brothers, Ampac Seed Company, and Peterson Seed Company. The assistance of these companies is gratefully acknowledged.

Table 1. Forage yields of single and mixed species of pasture grasses and forage legumes at Hotchkiss, Colorado, 1999.

Entry	Cut 1	Cut 2	Total		Average air-dry fraction	
	June 16	Aug. 31	1999	1998		
-----tons/acre-----						
1. Bromegrass 'Matua'	2.10	2.69	6.38	1.58	7.96	33.0
2. Creeping foxtail 'Garrison'	1.85	1.48	4.22	0.90	5.12	28.5
3. Reed canarygrass 'Venture'	1.76	2.25	5.25	1.24	6.49	31.1
4. Tall fescue 'Advance'	1.78	1.94	5.15	1.42	6.57	27.4
5. Orchardgrass 'Duke'	1.75	1.97	5.11	1.40	6.50	26.4
6. Orchardgrass 'Tekapo'	1.59	2.05	5.05	1.41	6.46	28.6
7. Meadowbrome 'Fleet'	3.01	1.71	5.87	1.16	7.03	31.5
8. Intermediate wheatgrass 'Oahe'	3.08	1.52	5.91	1.31	7.22	30.3
9. Pubescent wheatgrass 'Luna'	3.46	1.71	6.50	1.34	7.84	29.8
10. Slender wheatgrass 'San Luis'	2.32	2.08	5.14	0.74	5.88	28.2
11. Hybrid wheatgrass 'Newhy'	2.57	1.59	5.36	1.20	6.57	33.1
12. Beardless wildrye 'Shoshone'	2.27	2.05	4.94	0.63	5.57	29.3
13. Switchgrass 'Blackwell'	1.89	3.10	5.97	0.98	6.95	30.1
14. Big bluestem 'Kaw'	2.07	2.25	4.92	0.60	5.52	27.0
15. Timothy 'Climax'	2.40	1.97	5.09	0.72	5.82	27.7
16. Tall fescue 'Enforcer'	2.04	2.15	5.61	1.42	7.02	30.0
17. Intermediate wheatgrass 'Rush'	2.94	1.53	5.75	1.28	7.03	31.8
18. Altai wildrye 'Praireland'	2.05	1.77	4.47	0.65	5.12	28.1
19. Alfalfa 'AV120'	2.38	2.94	7.19	1.87	9.06	27.8
20. Forage chicory 'LaCerta'	1.97	3.05	6.86	1.84	8.70	17.4
21. Mountain brome 'Bromar'	2.58	2.25	6.18	1.35	7.53	32.2
22. Alfalfa 'Spredor III'	2.40	2.75	6.66	1.51	8.17	28.0
23. Birdsfoot trefoil 'ARS2620'	1.81	1.99	4.58	0.78	5.36	26.5
24. Ladino clover 'Will'	1.69	1.29	4.28	1.31	5.60	19.5
25. Redtop	2.03	1.69	4.41	0.70	5.12	28.1
26. Alfalfa 'AV120' + Birdsfoot trefoil 'Norcen'	2.60	2.78	7.28	1.90	9.19	27.4
27. Cicer milkvetch 'Windsor'	2.14	2.05	4.96	0.76	5.72	26.4
28. Sainfoin 'Remont'	2.37	1.89	5.18	0.93	6.11	28.5
29. Switchgrass + 'Newhy' (alternate seed rows)	2.62	2.67	6.45	1.16	7.61	32.5
30. Switchgrass + tall fescue (alternate seed row)	1.68	2.27	5.25	1.30	6.54	29.1
31. Switchgrass + 'Newhy' (mixed)	2.26	1.66	5.10	1.18	6.28	32.8

Table 1 (continued). Forage yields of single and mixed species of pasture grasses and forage legumes at Hotchkiss, Colorado 1999.

Entry	Cut 1 June 16	Cut 2 Aug. 31	Total			Average air-dry fraction
			1999	1998	2-Yr	
			-----tons/acre ¹ -----			
32. Switchgrass + tall fescue (mixed)	1.90	2.22	5.39	1.28	6.67	26.8
33. Smooth brome + alfalfa (alternate seed rows)	2.44	2.80	7.14	1.90	9.05	29.1
34. Smooth brome + birdsfoot trefoil (alternate seed rows)	2.03	2.20	5.26	1.04	6.29	29.7
35. Smooth brome + cicer milkvetch (alternate seed rows)	2.13	2.28	5.40	0.98	6.38	31.1
36. Smooth brome + sainfoin (alternate seed rows)	2.31	2.09	5.66	1.26	6.92	30.7
37. Smooth brome + alfalfa (mixed)	2.67	2.87	7.42	1.88	9.30	28.2
38. Smooth brome + birdsfoot trefoil (mixed)	2.43	2.33	5.85	1.08	6.93	31.5
39. Smooth brome + cicer milkvetch (mixed)	2.57	2.49	6.16	1.10	7.27	31.3
40. Smooth brome + sainfoin (mixed)	2.40	2.23	5.71	1.09	6.80	29.9
41. 'Newhy' + alfalfa (alternate seed rows)	2.47	2.71	6.96	1.78	8.74	28.0
42. 'Newhy' + birdsfoot trefoil (alternate seed rows)	2.54	1.84	5.52	1.15	6.67	31.1
43. 'Newhy' + cicer milkvetch (alternate seed rows)	2.55	1.77	5.52	1.20	6.73	31.6
44. 'Newhy' + sainfoin (alternate seed rows)	2.61	1.85	5.61	1.15	6.76	28.7
45. Smooth brome + orchardgrass + meadow brome	1.82	1.95	4.86	1.09	5.96	29.0
46. Smooth brome + orchardgrass + meadow brome + alfalfa	2.71	3.00	7.67	1.96	9.64	27.9
47. Smooth brome + orchardgrass + intermediate wheatgrass	2.20	1.84	5.43	1.39	6.82	28.8
48. Smooth brome + orchardgrass + intermediate wheatgrass + alfalfa	2.52	2.63	6.90	1.76	8.66	26.9
49. Smooth brome + orchardgrass + meadow brome + creeping foxtail	1.93	1.97	5.15	1.25	6.40	29.5
50. Smooth brome 'Bounty'	2.51	1.97	5.54	1.06	6.60	31.6
Average	2.28	2.16	5.68	1.24	6.92	29.0
CV (%)	15.50	14.10	10.80	14.70	10.60	5.10
LSD (0.05)	0.49	0.43	0.85	0.25	1.02	2.07

In entries 29-49, we used 'Blackwell' switchgrass, 'Fawn' tall fescue, 'Manchar' smooth brome, 'AV120' alfalfa, 'Norcen' birdsfoot trefoil, 'Remont' sainfoin, 'Windsor' cicer milkvetch, 'Tekapo' orchardgrass, 'Regar' meadow brome, 'Oahe' intermediate wheatgrass, and 'Garrison' creeping foxtail.

¹ Yields were calculated on an air-dry basis.

SOIL TEST BASED FERTILIZER RECOMMENDATIONS FOR IRRIGATED GRASS HAY

A. Wayne Cooley and Jessica G. Davis

SUMMARY AND RECOMMENDATIONS

We compared a farmer's standard fertilizer practice with Colorado State University's fertilizer recommendations (based on soil testing) in an irrigated grass hay field. Soil sampling and following CSU's fertilizer recommendations increased hay yield by 1700 lbs/acre and increased profit (above the cost of the additional fertilizer) by \$40/acre. Therefore, soil testing increased profit, and CSU's fertilizer recommendations were found to be sound on the West Slope.

INTRODUCTION

Many farmers on the West Slope do not have confidence in Colorado State University's fertilizer recommendations because they feel they were developed for conditions on the eastern plains. The purpose of this study was to evaluate CSU's fertilizer recommendations for irrigated grass hay in the Tri-River Area. It is of critical importance that fertilizer recommendations in the Tri-River Area be economically sound so that production is not limited by soil fertility and money is not wasted on unnecessary fertilizers which can potentially pollute water bodies that are already suffering from high salt and selenium levels.

MATERIALS AND METHODS

We installed research plots in the Olathe area on the Wolf Cattle Company farm in 1998 to evaluate the soundness of CSU's fertilizer recommendations on the West Slope. The plots were large so that they could be fertilized and harvested with normal size farm equipment. Comparison was made between the farmer's standard practice and CSU's recommendations based on soil testing.

The field was planted in 1994 with 12 lbs/acre of orchardgrass (broadcast). Each year since planting, there has been 180 lbs N/acre applied split into three 60 lbs N/acre applications in the spring, after the first cutting, and after the second cutting. Soil samples were taken on March 23, 1998 (Table 1), and ammonium nitrate (34-0-0) and mono-ammonium phosphate (11-52-0) fertilizers were applied at three times throughout the growing season (Table 2). Plots were 60 feet wide by 1,265 feet long, and there were three replicates in a randomized complete block design. Three cuttings 28 feet wide were taken on May 29, 1998 (baled on June 1, 1998), July 3, 1998 (baled on July 11, 1998), and September 16, 1998 (baled on September 20, 1998).

RESULTS AND DISCUSSION

The plots fertilized following CSU's recommendations produced about 1,700 lbs more per acre than the farmer's "standard" application practice (Tables 3 and 4). The additional N and P recommended by CSU (based on soil testing) increased yields significantly on cuttings one and three and the total. In addition, the economics show an increase in return by \$40/acre.

ACKNOWLEDGMENTS

This research would not have been possible without the cooperation of Wolf Cattle Company (Wayne Wolff and John Jackson) and West Slope Ag (Leon Jensen and Eldon Handke). Funding came from Colorado State University's CE/AES Initiative Grants, and we are especially grateful to Crandal Mergelman and Jason Hovey for their work in the field.

Table 1. Soil test results from Wolf Cattle Company (1998).

pH	Salts	Organic matter	Nitrate-N	Phosphorus	Potassium
	mmhos/cm	%	-----	ppm-----	
7.7	4.1	2.2	4	7.1	208

Table 2. Fertilizer treatments at Wolf Cattle Company (1998).

	April 16	June 8	July 20	Total N Applied	Total P ₂ O ₅ Applied
				-----lbs/acre-----	
Standard Practice	88-0-0	46-0-0	46-0-0	180	0
CSU's Recommendations	132-60-0	73-0-0	73-0-0	278 ¹	60

¹CSU's precise recommendations were for 265 lbs N/acre and 40 lbs P₂O₅/acre.

Table 3. Hay yields at each cutting.

	First Cutting	Second Cutting	Third Cutting
	-----lbs/acre-----		
Standard Practice	1852 B ¹	1001 A	2594 B
CSU's Recommendations	2630 A	1356 A	3121 A

¹Treatments with the same letter are not significantly different (p<0.05) by analysis of variance.

Table 4. Yields and economics at Wolf Cattle Company (1998).

	Total Yield	Hay Value ¹	Fertilizer Cost ²	Return ³
	lbs/acre	-----\$/acre-----		
Standard Practice	5448 B ⁴	\$272.39	\$55.65	\$216.74
CSU's Recommendations	7117 A	\$355.84	\$99.36	\$256.48

¹Hay price was \$100/ton.

²Cost was \$0.105/lb for ammonium nitrate and \$0.15/lb for 11-52-0.

³Return = Value minus Fertilizer Cost.

⁴Treatments with the same letter are not significantly different ($p < 0.05$) by analysis of variance.

WINDROW GRAZING: AN ALTERNATIVE TO FEEDING HAY IN THE TRI-RIVER AREA OF COLORADO

Robbie Baird-LeValley

SUMMARY AND RECOMMENDATIONS

Grazing of windrowed forages has been used successfully in various locations to reduce the costs of winter feeding, but had not been tried in the Tri-River Area of Colorado where snow cover is less consistent and fall rains more prevalent. A trial was conducted in 1998 at the Campbell Ranch near Hotchkiss in which 112 cows grazed windrows from 31 December 1998 to 19 January 1999. Forage quality and cow condition were monitored during the trial. The cows efficiently utilized the windrows once access was limited using electric fence. Cow condition did not change during the trial. Crude protein content of the windrows was higher than either the standing or harvested forage of the same type. The cows did not require supplemental protein while grazing the windrows. The overall cost savings for windrow grazing versus feeding harvested forages was \$13.50 per cow (\$1,512 total) for this 20 day trial. Initial findings indicate that windrow grazing can be used as part of an overall forage program to cut winter feeding costs in the Tri-River Area.

INTRODUCTION

Windrow grazing has been used successfully in Canada, Utah, and Wyoming as well as the San Luis Valley and Gunnison areas of Colorado. This practice involves cutting forage when it is at optimal nutrition and raking it into windrows. Animals are allowed to graze the windrows at a later point. It has proven successful in climates where there is consistent snow cover and it can significantly reduce the cost of harvesting and feeding hay (Brummer and Haugen, 1997). Windrow grazing had not been tried in the Tri-River Area (Montrose, Delta, Ouray and Mesa counties) of Colorado where snow cover is less consistent and fall rains more prevalent.

MATERIALS AND METHODS

A trial was set up in the fall of 1998 near Hotchkiss, Colorado on the Campbell Ranch (Elevation is listed at 6,500 feet). The test area was a tall fescue grass hay field that had traditionally been harvested in June and August with an additional fall grazing. For purposes of this study, ten acres that would normally have been cut a second time for hay in late August was windrowed with a 12-foot swather on December 1, 1998. Two days later, three windrows were raked into one, which was approximately 3 feet in diameter. The weather in the fall and winter of 1998 was above average for temperature and rainfall (Colorado Climate Center 1998). Due to the significant amount of fall rain, the hay was not harvested as early as desired. Ideally, the hay would have been harvested earlier than December 1 to capture more of the forage quality.

Forage samples were taken from windrows and adjacent standing pasture. The standing forage had been harvested twice and had a stubble height of approximately 10 inches. Forage

samples were taken every two weeks until harvested by cows. Samples were analyzed for crude protein, digestible protein, acid detergent fiber, neutral detergent fiber, energy, and macronutrients.

A total of 112 cows started grazing the windrows on December 31, 1998. The cows were in the last trimester of pregnancy and had a frame score of 5.5 and body condition score (BCS) of 6.5. At the start of the trial, the cows were given access to two windrows at a time. The remaining windrows were restricted using electric fence. When it was time to move the fence, the cows were moved to an adjoining field. Once the fence was moved, the cows were let back in. During the time the cows were on the windrows, they also had access to standing pasture.

RESULTS AND DISCUSSION

A heavy wet snow fell two days after the cows were put on trial. The cows did break through the ice and snow that was on top of the windrows, however, they were not efficiently using the feed. The cow's saliva produced additional ice on the windrows. To alleviate this problem, the cows were restricted to one windrow every other day. Once this adjustment was made, the cows increased utilization of the windrowed feed. Similar results have been observed in Gunnison.

The grass underneath the windrows was insulated and stayed green until harvested by the cows. This provided additional high quality forage. The cows utilized the windrows efficiently. BCS did not change during the trial. The 112 cows stayed on the 10 acres from December 31, 1998 to January 19, 1999. This equates to 2,128 animal days.

Traditionally, these cows would have been fed harvested round bales every day. The producer estimates that this type of feeding costs \$25 per day including time and equipment.

Traditionally, these 10 acres yielded 35 tons of hay per year. The second cutting, which was windrowed for this study, normally yielded about 1.5 tons per acre which would have fed the same 112 cows for only 9.5 days compared to the 20 days that were achieved by windrow grazing.

The cows were on a higher level of protein when utilizing the windrows versus the standing or harvested forage. The following table shows the nutritional values of the windrows, standing, and harvested forages.

Forage samples indicated that protein supplementation was not needed when the cows were grazing the windrowed forage. Traditionally, the cows were supplemented with protein at a cost of .26/head/day. This equates to cost savings of \$582.40 for the 20 days of grazing.

The protein in the windrows did not change significantly from the time of harvest till the cows were turned in. The protein tested 8.0% at the time of cutting and 7.8% at the time of grazing. Neutral detergent fiber and acid detergent fiber stayed at constant levels throughout the trial. There was no mold detected in the windrows at any time during the trial.

Total cost savings for windrow grazing includes:

Harvesting costs	\$ 430.00
Protein supplementation	582.40
Feeding costs	500.00
Total	\$1,512.40

This equates to cost savings of \$13.50 per cow.

Initial findings indicated that windrow grazing would work in the Tri-River Area. Additional trials need to experiment with cutting the hay earlier, grazing the spring forage to delay maturity, and further defining forage quality.

ACKNOWLEDGEMENTS

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LITERATURE CITED

Brummer, J.E. and M. Haugen. 1997. Windrow grazing at high elevations. Southern Rocky Mountain Forage and Livestock Conf., November 19-21, 1997, Monte Vista, Colo. 4 p.

Colorado Climate Center. 1999. Web page.

Table 1. Comparison between traditional versus windrow inputs based on a 10-acre trial site and feeding 112 cows for 20 days.

	Traditional	Windrow	Net
Swathing	\$100.00	\$100.00	\$ 0.00
Baling	\$150.00		\$150.00
Raking	\$ 30.00	\$ 30.00	\$ 0.00
Stacking	\$150.00		\$150.00
Feeding	\$500.00		\$500.00
Electric fence	\$ 0.00	\$ 75.00	<\$ 75.00>
Moving cows	\$ 0.00	\$ 50.00	<\$ 50.00>
Total	\$930.00	\$255.00	\$675.00

Table 2. Nutritional comparison of windrows, standing and harvested forage at the time the cows were harvesting the windrows.

	Windrows	Standing	Harvested
Moisture, %	58.3	35.9	12.0
Dry Matter, %	41.7	64.1	88.0
Crude Protein, %	7.8	4.6	6.8
Acid Det. Fiber, %	41.5	40.1	33.5
Neutral Det. Fiber, %	61.9	60.7	52.3
Total Dig. Nut., %	58.1	59.4	57.5
NE Main. (Mcal/lb)	0.49	0.48	0.56
NE Gain (Mcal/lb)	0.24	0.25	0.30
NE Lact (Mcal/lb)	0.46	0.44	0.59
Calcium, %	0.84	0.80	0.68
Phosphorus, %	0.11	0.08	0.23

EVALUATION OF VARIETIES AND METHODS OF ESTABLISHING BIRDSFOOT TREFOIL INTO MOUNTAIN MEADOWS

Joe E. Brummer and N. Don Rill

SUMMARY AND RECOMMENDATIONS

Birdsfoot trefoil was evaluated as a potential legume for interseeding into mountain meadows. Five varieties ('Carroll', 'Norcen', 'Leo', 'Tretana', and 'Empire') were interseeded into three types of seedbeds (Rototilled, sprayed with Roundup, or directly seeded with no suppression). Yields averaged over all varieties increased 1,000 lbs/acre compared to the unseeded control. All varieties significantly increased yields with the 'Norcen' and 'Leo' varieties having slightly higher yields compared to the others tested. Crude protein content of the hay in the seeded plots was increased an average of 2.4 percentage points compared to the unseeded control (7.5 vs 9.9%). Rototilling or spraying with Roundup prior to seeding increased contribution of birdsfoot trefoil to the hay by 50 and 100%, respectively, compared to direct seeding. This study demonstrated that birdsfoot trefoil can be successfully interseeded into mountain meadows. The greatest success of establishing trefoil can be achieved by using the right variety, 'Norcen' or 'Leo', and suppressing the vegetation prior to seeding. Once established, trefoil can contribute significantly to both yield and quality, especially crude protein content.

INTRODUCTION AND OBJECTIVES

Birdsfoot trefoil (*Lotus corniculatus*) is a legume with growth characteristics similar to alfalfa, but it has the added advantage of being non-bloating when grazed as standing green forage. Total yearly production is generally less than alfalfa due primarily to a slower rate of regrowth. However, first cutting yields are comparable which is of primary importance in mountain meadow areas where the short growing season generally precludes more than one cutting. Although quality of birdsfoot trefoil does not typically peak as high as for alfalfa, its rate of decline in forage quality with maturity is slower. This trait has positive implications for producers that cannot realistically harvest all their hay at peak quality due to constraints such as time, labor, or weather.

Although birdsfoot trefoil has been included in legume evaluations conducted by the Mountain Meadow Research Center in the past, a thorough evaluation of available varieties has not been undertaken. Also, because birdsfoot trefoil has low seedling vigor and does not compete well with existing vegetation, management practices to reduce competition during the establishment phase need to be investigated. The objective of this study was to evaluate varieties of birdsfoot trefoil potentially adapted for use in mountain meadows and to determine the impact of different seedbed preparations on establishment success.

MATERIALS AND METHODS

This study was conducted on the Trampe Ranch approximately 6.5 miles north of Gunnison at 7,800 ft elevation. Soil at the site is a Fola cobbly sandy loam. This soil is deep, well-drained, and has rapid permeability which makes it ideally suited for introduction of deep rooted legumes. Although roots can penetrate to a depth of 60 inches or more, available water capacity is low which can create drought-like conditions if irrigation water is not adequate.

Birdsfoot trefoil was seeded on May 24, 1994 at the rate of 6 lbs pure live seed/acre. Varieties were: 'Carroll' - an Iowa release, 'Norcen' - a north central U.S. release, 'Leo' - a Canadian release, 'Tretana' - a Montana release, and 'Empire' - the first U.S. release developed from plants found in New York state. All varieties were inoculated just prior to seeding with standard inoculant containing the appropriate *Rhizobium* bacteria. Plots were seeded with a John Deere Powr-till® drill (Model 1550, 8 ft.). An unseeded plot was left as a control.

The different varieties were seeded into 3 types of seedbeds. The first consisted of seeding directly into the existing vegetation with no effort to suppress competition. The existing vegetation was approximately 4-6 inches tall at the time of seeding. This treatment was considered the control. The second seedbed treatment consisted of suppressing the existing vegetation with Roundup sprayed 2 weeks prior to seeding at the rate of 1 1/2 qts/acre. Although Roundup is supposed to kill all plants that it comes in contact with, it generally only suppresses the more vigorous perennial grasses allowing the interseeded seedlings to become established. The third seedbed treatment consisted of rototilling with a tractor-mounted rototiller to a depth of about 1 inch. The objective of this treatment was to eliminate or reduce shallow-rooted species such as Kentucky bluegrass and set back the deeper-rooted, desirable perennial grasses giving the seedlings time to become established.

Experimental design was a split-block with 3 replications. Plot size for each variety/seeding method combination was 10 x 24 ft. Each block measured 72 x 80 ft. The entire study area was fertilized with 80 lbs/acre of P₂O₅ just prior to seeding using triple superphosphate (0-45-0).

The study area was flood irrigated under the management of the landowner. Harvest of plots was timed to coincide with the landowner's normal haying which occurred in late July or early August each year. Plots were harvested with a New Holland mower/conditioner (9 ft, 3 in header) which left the forage in a windrow. The center 20 ft of each windrow was collected and weighed to estimate production. Two grab samples were collected per plot. The first was used to determine moisture content and overall hay quality. The second was separated into components of alfalfa, birdsfoot trefoil, clover, forbs, and grass to determine hay composition. Forage quality of individual components was also analyzed. Crude protein and in vitro dry matter digestibility were analyzed as measures of forage quality.

RESULTS AND DISCUSSION

Interseeding birdsfoot trefoil into existing mountain meadow vegetation increased total hay yield an average of 1,000 lbs/acre compared to the unseeded control (Table 1). All varieties significantly increased yield with the 'Leo' and 'Norcen' varieties leading to slightly higher yields than some of the others tested. Averaged over varieties, birdsfoot trefoil contributed 22% to total hay yield. The relationship between the amount of birdsfoot trefoil in the hay and total

yield was strong. Plots seeded with the 'Norcen' variety produced the highest total yield of 4,620 lbs/acre and had the highest contribution from birdsfoot trefoil of 26%. Plots seeded with the 'Tretana' variety had the lowest contribution of 19% and the lowest total yield of 3,960 lbs/acre.

Averaged across varieties, birdsfoot trefoil increased crude protein content of the hay 2.4 percentage points compared to the control (Table 2). As with yield, there was a trend of higher crude protein content in the hay as the contribution from birdsfoot trefoil increased. The 'Leo' and 'Norcen' varieties had the highest contribution to total yield of about 25% and the largest increase in crude protein content of the hay of about 3 percentage points. Basically, crude protein content of the hay went from a level that was marginal for dry, mature cows (7.5%) to one that was adequate for most classes of livestock.

In contrast to crude protein content, digestibility of the hay was slightly lowered as the amount of birdsfoot trefoil in the hay increased (Table 2). Digestibility of hay from plots seeded to 'Leo' and 'Norcen' birdsfoot trefoil was about 2.5 percentage points lower compared to hay from the unseeded control. This is in spite of the fact that birdsfoot trefoil alone was highly digestible (Table 7). The reason for the lower digestibility of the hay was probably related to lower digestibility of the grass component. Birdsfoot trefoil contributes nitrogen to the system through fixation plus leads to shading in the canopy which causes other plants to grow towards the light. Both of these factors contribute to steeper grass growth which lowers digestibility of this component. Since grass makes up about 60% of the hay in seeded plots (Table 1), it has a dominating effect on overall digestibility of the hay.

Total hay yield was not significantly affected by either the spray or tillage seedbed preparations although there was a trend of higher yields compared to the control (Table 3). The trend towards higher yields in these plots was probably due to the greater contribution of birdsfoot trefoil. Trefoil contributed twice as much to total hay yield in sprayed plots and 50% more in tilled plots compared to the control (Table 3). This result emphasizes the need to suppress the existing vegetation in some manner prior to seeding to improve establishment success of birdsfoot trefoil. Even in thin stands, such as was found in this meadow, suppression of the existing vegetation will lead to greater establishment success.

Method of seeding did affect both crude protein content and digestibility of the hay (Table 4). Tilling the seedbed prior to interseeding decreased both crude protein content and digestibility of the hay compared to the control. The trend with tilling was for increased grass and decreased alfalfa and clover composition. Also, the trefoil did not establish as well in this treatment compared to the spray treatment. These changes in composition all interacted to cause the decreases with the driving force again being the increase in grasses.

Environmental variables can cause fluctuations in both yield and composition from year to year and this study was no exception (Table 5). Yield in 1997 was influenced by the unseasonably wet spring and summer. Over 2,400 lbs/acre more hay was produced in 1997 compared to the more normal year of 1995. Composition also fluctuated widely depending on year. During the dry year of 1996, grass composition was higher compared to the other 2 years with normal to above normal precipitation. Clovers are known to cycle over time. In 1995, clover composition of the hay was high at 14% compared to 1996 when it was only 1%. The cycling nature of clovers plus the dry conditions probably resulted in the low composition

observed in 1996. Birdsfoot trefoil responded very well to the wet year in 1997 by comprising almost twice as much of the hay as in the dry 1996 year.

Crude protein content of the hay was not influenced by year averaging almost 9.5% (Table 6). Digestibility of the hay, however, was affected by year. The highest digestibility was recorded in 1996. The dry conditions during this year limited growth and kept plants, especially grasses, in a more immature stage. Plants that are more immature are more highly digestible.

ACKNOWLEDGEMENTS

Appreciation is expressed to Bill Trampe, Gunnison Rancher, for his support of this project, use of his land, and his efforts in irrigating the plots.

Table 1. Effect of interseeding various varieties of birdsfoot trefoil on yield and composition of mountain meadow hay.

Variety ¹	Yield ²	Grass	Birdsfoot Trefoil	Alfalfa	Clover	Forbs
	lb/acre	-----%				
Control	3300 a	83 b	0 a	5 a	8 a	4 a
Carroll	4240 bc	66 a	20 b	4 a	6 a	4 a
Empire	4240 bc	65 a	19 b	7 a	6 a	3 a
Leo	4470 c	56 a	24 b	12 a	5 a	3 a
Norcen	4620 c	59 a	26 b	5 a	6 a	4 a
Tretana	3960 b	64 a	19 b	5 a	6 a	6 a

¹Variety means were averaged over seeding methods and years.

²Means within columns followed by the same letter are not significantly different (P>0.05).

Table 2. Effect of interseeding various varieties of birdsfoot trefoil on crude protein (CP) content and in vitro dry matter digestibility (DMD) of mountain meadow hay.

Variety ¹	Crude Protein ²	Dry Matter Digestibility
	-----%	
Control	7.5 a	65.6 c
Carroll	9.4 b	64.5 abc
Empire	9.8 b	65.0 abc
Leo	10.5 b	63.2 ab
Norcen	10.2 b	62.9 a
Tretana	9.5 b	65.2 bc

¹Variety means were averaged over seeding methods and years.

²Means within columns followed by the same letter are not significantly different (P>0.05).

Table 3. Effect of method of seeding (i.e. vegetation suppression method) birdsfoot trefoil on yield and composition of mountain meadow hay.

Suppress ¹	Yield ²	Grass	Birdsfoot Trefoil	Alfalfa	Clover	Forbs
	lb/acre	-----%				
Control	3670 a	67 a	12 a	8 a	8 a	5 a
Spray	4300 a	61 a	24 b	7 a	5 a	3 a
Till	4450 a	70 a	18 b	4 a	5 a	3 a

¹Seeding method means were averaged over birdsfoot trefoil varieties and years.

²Means within columns followed by the same letter are not significantly different (P>0.05).

Table 4. Effect of method of seeding (i.e. vegetation suppression method) birdsfoot trefoil on crude protein (CP) content and in vitro dry matter digestibility (DMD) of mountain meadow hay.

Suppress ¹	Crude Protein ²	Dry Matter Digestibility
	-----%	
Control	9.6 b	66.3 b
Spray	10.0 b	64.9 ab
Till	8.9 a	62.0 a

¹Seeding method means were averaged over birdsfoot trefoil varieties and years.

²Means within columns followed by the same letter are not significantly different (P>0.05).

Table 5. Effect of year (i.e. environmental factors) on yield and composition of mountain meadow hay.

Year ¹	Yield ²	Grass	Birdsfoot Trefoil	Alfalfa	Clover	Forbs
	lb/ac	-----%				
1995	3650 a	59 a	15 a	7 a	14 b	5 a
1996	2710 a	75 b	13 a	7 a	1 a	4 a
1997	6060 b	62 a	26 b	5 a	4 a	3 a

¹Year means were averaged over birdsfoot trefoil varieties and seeding methods.

²Means within columns followed by the same letter are not significantly different (P>0.05).

Table 6. Effect of year (i.e. environmental factors) on crude protein (CP) content and in vitro dry matter digestibility (DMD) of mountain meadow hay.

Year ¹	Crude Protein ²	Dry Matter Digestibility
	-----%	
1995	9.5 a	61.8 a
1996	9.9 a	67.2 b
1997	9.0 a	64.3 ab

¹Year means were averaged over birdsfoot trefoil varieties and seeding methods.

²Means within columns followed by the same letter are not significantly different (P>0.05).

Table 7. Crude protein (CP) content and in vitro dry matter digestibility (DMD) of various components of mountain meadow hay following interseeding of birdsfoot trefoil. Samples were taken August 3, 1995.

Component ¹	Crude Protein ²	Dry Matter Digestibility
	-----%	
Alfalfa	14.1 b	56.7 a
Birdsfoot Trefoil	17.3 c	67.2 d
Clover	16.8 c	63.8 c
Forbs	7.6 a	61.8 bc
Grass	6.7 a	59.5 b

¹Varieties were composited or averaged across seeding methods.

²Means within columns followed by the same letter are not significantly different (P>0.05).

EFFECTS OF MINIMUM TILLAGE AND NITROGEN FERTILIZATION ON YIELD AND QUALITY OF MOUNTAIN MEADOW HAY

Joe E. Brummer, N. Don Rill, and Dwayne G. Westfall

SUMMARY AND RECOMMENDATIONS

Minimum tillage and nitrogen fertilization were investigated as practical methods of renovating mountain meadow soils high in organic matter at two sites within the Gunnison Basin. Three tillage treatments - Aerway aeration and ripping on either 6 or 12 in. centers - were investigated in conjunction with applications of 0, 100, or 200 lbs of nitrogen fertilizer per acre. Each of these treatments or treatment combinations were applied for 1, 2, or 3 consecutive years (1995, 1996, and 1997). Minimum tillage did not increase forage production at either site. When averaged across years, tillage caused yield decreases of up to 32%. Ripping on 6 in. centers, the most invasive treatment, lead to the greatest yield decrease. Nitrogen fertilization increased forage yields up to 85% at the 200 lb/acre application rate. The effect of nitrogen on crude protein content was variable depending on site and year. However, digestibility of the forage was decreased an average of 4 to 10 percentage points by the addition of nitrogen. Grass composition increased and clover composition decreased in response to the additional nitrogen. Based on the results from this study, minimum tillage of any type is not beneficial for improving forage productivity of wet, low-lying areas of mountain meadows. Nitrogen fertilization is still the most practical means of improving productivity on these types of sites.

INTRODUCTION AND OBJECTIVES

Flood irrigated hay meadows throughout the intermountain region typically develop a dense layer of organic matter. This layer can be as thick as 4 inches and contain large reserves of nutrients. It has been estimated that as much as 5,400 lbs of total nitrogen/acre are contained within the top 4 inches. However, this source of nitrogen is unavailable for plant uptake since the nitrogen is in a fixed organic form. To become available, the fixed nitrogen must undergo decomposition and mineralization, a process which is microbial driven and temperature dependent. In mountain meadows, decomposition and mineralization are slow due to continuous flood irrigation, cold soil temperatures, and short growing seasons. It has been demonstrated that complete renovation (plowing and reseeding) is an effective way to enhance mineralization and boost hay production, but this usually is not practical for mountain meadows. The shallow, rocky soils as well as the thick organic layer make plowing difficult and expensive. A primary objective of this study was to evaluate methods of minimum tillage to promote decomposition and nitrogen mineralization that would minimally disrupt annual forage production. The effects of additional nitrogen in conjunction with minimum tillage as well as the effects of multi-year applications were also considered in the study objective.

MATERIALS AND METHODS

This study was conducted at two locations. The first site was located on the Guerrieri Ranch 3 miles north of Gunnison, Colorado off County Road 10 while the second site was located on the Spann Ranch 16 miles north of Gunnison off Highway 135. Main plot treatments consisted of three tillage methods and a control. An Aerway spike-tooth aerator (AW) was the first treatment. The second and third tillage treatments consisted of a series of 17 inch diameter coulters followed closely by $\frac{3}{4}$ inch wide shanks. The coulters/shank combination was set on 6 and 12 inch centers for the R6 and R12 treatments, respectively. Each tillage main plot treatment was split into three subplots. The subplots were treated 1, 2, or 3 consecutive years. Each subplot was split once more to accommodate two levels of nitrogen fertilization and a control. Ammonium nitrate was used as a source of nitrogen at rates of 100 and 200 lbs of nitrogen/acre. This split-split plot configuration created 36 different tillage/application year/N fertilization combinations. The experimental design was a randomized complete block with four replications at both the Guerrieri and Spann sites.

The tillage/fertilizer treatments were applied during the spring of 1995, 1996, and 1997 in late April or early May depending on when snow melt occurred. Annual harvest dates coincided with the normal harvest efforts of the producer which ranged from late July to early September. Yield estimates were obtained from each plot and samples were collected for forage quality analysis which included crude protein (CP) and in vitro dry matter digestibility determinations. Shifts in vegetative composition caused by tillage and fertilization were determined by separating subsamples from each treatment into the major vegetative groups (grasses, clovers, and forbs). Soil samples were also taken to determine ammonium, nitrate, total carbon, and total nitrogen levels. The soil samples were collected prior to treatment initiation in 1995 and annually before treatment application in 1996 and 1997.

RESULTS AND DISCUSSION

Tillage did not increase forage production at either the Guerrieri or Spann sites. When averaged across years, tillage actually decreased yield. The AW, R12, and R6 treatments caused declines in yield of 21, 27, and 32%, respectively, at the Guerrieri site, and declines of 20, 9, and 13%, respectively at the Spann site (Table 1). The addition of nitrogen boosted yield by 58% at the 100 lb/acre rate and 85% at the 200 lb/acre rate at the Guerrieri site. At the Spann site, yield increased by 51% at the 100 lb/acre rate and 59% at the 200 lb/acre rate (Table 2). The effect of the additional nitrogen on yield was the same for each of the tillage treatments.

Tillage had no impact on crude protein or digestibility, unlike the additional nitrogen, which did affect forage quality. At the Guerrieri site, 200 lb/acre of additional nitrogen caused a slight increase in crude protein content in 1995 when compared to no nitrogen and the 100 lb/acre rate. During the following two seasons (1996 and 1997), both the 100 and 200 lb/acre rates decreased crude protein content (Table 3). At the Spann site, both the 100 and 200 lb/acre rates decreased crude protein content in 1995 (Table 4). In 1996, there was no significant difference in crude protein content between fertilized and unfertilized plots and only the 100 lb/acre rate caused a decrease in crude protein content in 1997 at the Spann site. The effect of nitrogen on crude protein content was variable depending on site and year. Where no additional nitrogen was

added, forage digestibility averaged 66.0 and 66.4% at the Guerrieri and Spann sites, respectively (Table 5 and 6). The addition of nitrogen at the 100 and 200 lb/acre rates decreased digestibility an average of 4 and 10 percentage points at the Guerrieri and Spann sites, respectively.

The vegetative composition was impacted by the addition of nitrogen. At the Spann and Guerrieri sites, the addition of nitrogen at 100 and 200 lbs of N/acre caused an increase in grass and a decrease clover (Table 7 and 8). This shift in composition was partially responsible for the decrease in both crude protein and digestibility of the forage. Tillage had no impact on the vegetative components of the forage.

The decision of whether to fertilize or not depends on an individual producer's objective. If the need is for increased forage production, then nitrogen fertilization is a rapid and convenient means to do so. However, nitrogen will stimulate grass production while legumes, such as clovers, will be sacrificed. The loss of the legume component coupled with the increased fiber content of the grass component has the potential to decrease overall forage quality, which may be undesirable - quantity versus quality needs to be considered. If maintaining legumes in the stand is of importance, adding nitrogen at 100 or 200 lbs/acre should not be considered. Nitrogen fertilization rates lower than those used in this study may be applicable towards promoting overall production while maintaining legumes.

The benefits associated with minimum tillage appear to depend on the characteristics of the individual meadow. Based on the three years results from this study, tillage of any type is not beneficial in wet, low-lying areas of a meadow and that tillage of such areas can actually decrease overall production. This may be partially due to disturbance of vegetation caused by the tillage equipment and partially due to making an already wet area even wetter by opening up the sod mat so it can trap and retain even more water than normal. On compacted, side sloping areas of a meadow, tillage may help improve water infiltration and distribution therefore improving irrigation efficiency and forage productivity.

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Appreciation is expressed to Lee and Ken Spann and Richard and Phyllis Guerrieri for use of their land for these trials.

Table 1. Effect of minimum tillage without additional nitrogen on dry matter yield of mountain meadow hay at the Guerrieri and Spann sites. (Three year average from 1995 to 1997)

Tillage Treatment	Guerrieri Site	Spann Site
	-----lbs/acre-----	
No Tillage (Control)	5130	3880
Aerway aerator (AW)	4090	3090
Ripped on 12" centers (R12)	3770	3540
Ripped on 6" centers (R6)	3490	3370

Table 2. Effect of nitrogen fertilization without tillage on dry matter yield of mountain meadow hay at the Guerrieri and Spann sites. (Three year average from 1995 to 1997)

Nitrogen Added	Guerrieri Site	Spann Site
lbs/acre	-----lbs/acre ^a -----	
0	4130 a	3470 a
100	6520 b	5250 b
200	7620 c	5500 b

^aMeans within columns followed by the same letter are not significantly different (P>0.05)

Table 3. Effect of nitrogen fertilization on crude protein content of forage at the Guerrieri site during three years - 1995 to 1997. (Averaged across tillage treatments)

Nitrogen Added	1995	1996	1997	3 year Average
lbs/acre	-----% ^a -----			
0	9.2 a	8.2 c	8.8 a	8.7 x
100	8.8 a	7.7 d	7.6 d	8.0 x
200	10.4 b	7.8 d	7.6 d	8.6 x

^aMeans within rows and columns followed by the same letter are not significantly different (P>0.05)

Table 4. Effect of nitrogen fertilization on crude protein content of forage at the Spann site during three years - 1995 to 1997. (Averaged across tillage treatments)

Nitrogen Added	1995	1996	1997	3 year Average
lbs/acre	-----% ^a -----			
0	11.0 a	8.5 b	10.9 a	10.1 x
100	8.5 b	7.4 b	8.8 b	8.2 y
200	8.6 b	7.1 b	10.4 a	8.7 z

^aMeans within rows and columns followed by the same letter are not significantly different (P>0.05)

Table 5. Effect of nitrogen fertilization on digestibility of forage at the Guerrieri site during 1995 and 1996. (Averaged across tillage treatments)

Nitrogen Added	1995	1996	2 year average ^a
lbs/acre	-----%		
0	68.2	63.7	66.0 x
100	64.2	60.7	62.5 y
200	63.6	59.9	61.8 y
Average^a	65.3 a	61.4 b	63.4

^aMeans within rows and columns followed by the same letter are not significantly different (P>0.05)

Table 6. Effect of nitrogen fertilization on digestibility of forage at the Spann site during 1995 and 1996. (Averaged across tillage treatments)

Nitrogen Added	1995	1996	2 year average ^a
lbs/acre	-----%		
0	69.3	63.5	66.4 x
100	61.2	54.7	57.9 y
200	58.7	51.3	55.0 y
Average^a	63.0 a	56.5 b	59.8

^aMeans within rows and columns followed by the same letter are not significantly different (P>0.05)

Table 7. Effect of nitrogen fertilization on composition of mountain meadow hay at the Guerrieri site. (Averaged across tillage treatments and three years - 1995 to 1997)

Nitrogen Added	Grass	Clover	Forbs
lbs/acre	-----%		
0	92.6	5.9	1.5
100	97.9	0.9	1.2
200	98.9	0.3	0.8

Table 8. Effect of nitrogen fertilization on composition of mountain meadow hay at the Spann site. (Averaged across tillage treatments and three years - 1995 to 1997)

Nitrogen Added	Grass	Clover	Forbs
lbs/acre	-----%		
0	90.5	8.2	1.3
100	98.3	1.2	0.5
200	98.3	1.1	0.6

RESIDUAL EFFECTS OF MINIMUM TILLAGE AND NITROGEN FERTILIZATION ON HAY YIELD AND SPECIES COMPOSITION OF MOUNTAIN MEADOWS

Joe E. Brummer, N. Don Rill, and Dwayne G. Westfall

SUMMARY AND RECOMMENDATIONS

The residual effects of minimum tillage and nitrogen fertilization treatments on hay yield and species composition were quantified on two mountain meadows near Gunnison, Colorado in 1998. Tillage treatments consisting of ripping on 6 or 12 in. centers or Aerway aerating did not have any detectable positive or negative effects on hay yield or species composition in 1998 (1 year following end of treatments), even when applied for three consecutive years. Nitrogen fertilization at the 200 lb/acre rate did have a positive residual effect on yield at one site but not the other. Nitrogen generally only affects yield in the year of application. There were no residual effects on yield at either site associated with the 100 lb/acre rate. Species composition was affected by both rate of nitrogen application and number of consecutive times applied. The higher the rate and the more times applied, the greater was the change. Meadow foxtail and wheatgrass increased while Kentucky bluegrass, rushes, sedges, and clovers decreased. Nitrogen fertilization can be used to both increase hay yields and cause shifts in species composition of mountain meadows. Some shifts may be positive (increased meadow foxtail, decreased sedges and rushes) or negative (less of clovers).

INTRODUCTION AND OBJECTIVES

Flood irrigated hay meadows throughout the intermountain region typically develop a dense layer of organic matter. This organic matter layer can be as thick as 4 inches and contain large reserves of nutrients. It has been estimated that as much as 5,400 lbs of total nitrogen (N)/acre are contained within the top 4 inches. However, this source of N is unavailable for plant uptake since the N is in a fixed organic form. To become available, the fixed N must undergo decomposition and mineralization, a process which is microbial driven and temperature dependent. In mountain meadows, decomposition and mineralization are slow due to continuous flood irrigation, cold soil temperatures, and short growing seasons. It has been demonstrated that complete renovation (plowing and reseeded) is an effective way to enhance mineralization and boost hay production but this usually is not practical for mountain meadows. The shallow, rocky soils as well as the thick organic layer make plowing difficult and expensive. The primary objective of this study was to evaluate the effects of various minimum tillage practices on hay yield and quality. In theory, the application of small-scale soil disturbances should promote organic matter decomposition and N mineralization while minimally disrupting annual forage production. The effects of additional N in conjunction with minimum tillage as well as the effects of multiple-year applications were also evaluated. The yield and quality results have been presented in previous progress reports. This report will present results on the residual effects that the tillage and N treatments had on hay yield and species composition.

MATERIALS AND METHODS

This study was conducted at two locations. The first site was located on the Guerrieri Ranch 3 miles north of Gunnison, Colorado off County Road 10 while the second site was located on the Spann Ranch 16 miles north of Gunnison off Highway 135. Main plot treatments consisted of three tillage methods and a control. An Aerway spike-tooth aerator (AW) was the first treatment. The second and third tillage treatments consisted of a series of 17 inch diameter coulters followed closely by $\frac{3}{4}$ inch wide shanks. The coulters/shank combination was set on 6 and 12 inch centers for the R6 and R12 treatments, respectively. Each tillage main plot treatment was split into three subplots. The subplots were treated 1, 2, or 3 consecutive years. Each subplot was split once more to accommodate two levels of N fertilization and a control. Ammonium nitrate was used as a source of N at rates of 100 and 200 lbs of actual N/acre. This split-split plot configuration created 36 different tillage/application year/N fertilization combinations. The experimental design was a randomized complete block with four replications at both the Guerrieri and Spann sites.

The tillage/fertilizer treatments were applied in late April or early May of 1995, 1996, and 1997 depending on when snow melt occurred. Annual harvest dates coincided with the normal harvest efforts of the producer which ranged from late July to early September. The effects of the tillage and fertilizer treatments on species composition of each meadow were determined in May of 1998 using a modified point technique. This technique determined species composition based on basal area. Hay yields were also taken in 1998 to determine the residual effects of the previous 3 years of treatments on meadow productivity.

RESULTS AND DISCUSSION

Yield

No tillage or fertility treatments were applied in 1998. Therefore, evaluation of yields during this year should reveal any additive or residual effects related to the treatments. Applying tillage treatments for 1, 2, or 3 consecutive years did not have any detectable positive or negative effects on hay yield in 1998 at either site. Evaluation from previous years during which the tillage treatments were actually applied also revealed no positive yield responses. The more common response was for yields to decrease during the year the tillage treatments were applied. Based on these findings, tillage disturbances such as ripping or Aerway aeration should not be applied to mountain meadow soils that have a large accumulation of organic matter (peat layer) at the surface. This is not to say that such disturbances would not be beneficial on heavier type soils (clays) that may be compacted or have compacted layers. From a practical standpoint, ripping or other forms of minimum tillage should be viewed as water management tools. Meadows with sloping topography or other hard to irrigate areas may be prime candidates for these types of management practices. However, one should use caution because there is little research data from mountain meadows that supports or disputes the potential benefits from applying these practices to these types of areas.

Adding N fertilizer did have a residual effect on yield that was positive at the Guerrieri site (Table 1). Even N that was applied only once in 1995 at the 200 lb/acre rate was still positively affecting yields by 320 lbs/acre 3 years later. The residual yield response from the 200 lb N/acre

rate was consistently positive (1996 was not significant) regardless of whether the N was applied 1, 2, or 3 consecutive times. Therefore, the 3 year average yield response from this N rate equaled 300 lbs more hay per acre compared to the unfertilized control. The 100 lb N/acre rate did not lead to a significant yield increase compared to the unfertilized control.

At the Spann site, there were no residual yield responses, positive or negative, related to either rate of N application (Table 2). The positive residual response to the 200 lb N/acre rate at the Guerrieri site is not well understood. It appears that the heavy application of N, even for only 1 year, stimulated increased mineralization or cycling of the N tied up in the large organic pool. N applied in fertilizer is generally either quickly taken up by the plants, leached beyond the root zone, or is tied up in the organic pool. Single applications above about 150 lbs N/acre should provide a surplus of N to the system. This surplus possibly stimulated the microbial population which is responsible for mineralization of N in the organic matter pool.

One of the common complaints from producers that have used N fertilizer for several years is that yields drop below pre-fertilization levels if they ever quit applying the N. The positive yield response at the Guerrieri site combined with no residual response at the Spann site provides evidence against the perceived negative effects of N fertilization.

Species Composition

The species composition of meadows can be influenced by many factors such as soil type, water management, N and phosphorus fertility, interseeding, and others. One would theorize that tillage practices, such as ripping, could also cause changes in species composition of meadows. However, none of the tillage treatments investigated in this study caused measurable changes in species composition at either site.

N fertilization, however, did have a substantial impact on species composition at both sites (Tables 3 and 4). N generally stimulates grasses, especially those that are improved or introduced, to the detriment of clovers and other forbs. These general trends were evident at both sites.

Meadow foxtail is an introduced grass species that increased by 31 and 42% with the addition of 100 and 200 lbs N/acre, respectively, at the Guerrieri site. Wheatgrass is a vigorous, rhizomatous species that also responded well to N applications at this site increasing by 23 and 62% at the 100 and 200 lb/acre rates, respectively. Kentucky bluegrass is a low growing species that did not compete well with the above 2 larger statured grasses that were stimulated by the N. Bluegrass initially dominated the composition (42%) at this site, but was affected by both N rates decreasing an average of 20%. Clovers made up a small percentage of the composition at the Guerrieri site and no significant changes were detected although the trend was for a decrease. The sedges were also a minor part of the composition at this site but they were reduced 43% at the 200 lb/acre rate.

Meadow foxtail was the dominant species at the Spann site (Table 4). By adding N, it became even more dominant. However, the degree of increase was influenced by the rate and number of times that N was consecutively applied (Table 5). The length of time since N was last applied would also be interwoven in the response since plants would have had longer to recover under some treatments than others. Basically, the rate of increase in meadow foxtail was accelerated by the 200 compared to the 100 lb/acre rate. Applying 200 lbs N/acre for 3

consecutive years changed the composition from an average of 73 to 98% meadow foxtail. To most producers, this would be an undesirable change.

Meadow foxtail can be quite productive when fertilized but is often of low quality, especially crude protein content, unless cut early. The Spann meadow had an average composition of 10% clovers (Table 4). By adding N, composition of clovers was significantly decreased. The more times N was consecutively applied, the greater was the decrease with 3 consecutive years of application leading to no measurable clovers at either N rate (Table 5). As eluded to earlier, 1 application of N in 1995 either did not totally suppress the clovers or they have had time to partially recover or both.

The effect on the rush component at the Spann site was very similar to the decrease observed for clovers (Tables 4 and 5). Again, the more consecutive times N was applied, the greater was the measured decrease in rushes with 3 consecutive years of 200 lbs N/acre almost totally eliminating them from the composition. Since many mountain meadows have large compositions of rushes that are relatively low producing, several years of heavy N application may be useful as a management tool to decrease or eliminate them from the composition.

ACKNOWLEDGEMENTS

Appreciation is expressed to Lee and Ken Spann and Richard and Phyllis Guerrieri for use of their land for these trials.

Table 1. Effect of nitrogen applied one, two, or three years prior to 1998 on dry matter yield of mountain meadow hay at the Guerrieri site.

Nitrogen Added	Year Nitrogen was Last Applied			3 Year Average
	1995	1996	1997	
lbs/acre	----- tons/acre ^a -----			
0	2.16 a	2.15 a	2.35 a	2.22 a
100	2.25 ab	2.18 a	2.32 a	2.25 a
200	2.32 b	2.27 a	2.53 b	2.37 b
Average	2.24	2.20	2.40	

^aMeans within columns followed by the same letter are not significantly different ($P>0.05$). Means are averaged across tillage treatments.

Table 2. Effect of nitrogen applied one, two, or three years prior to 1998 on dry matter yield of mountain meadow hay at the Spann site.

Nitrogen Added lbs/acre	Year Nitrogen was Last Applied			3 Year Average
	1995	1996	1997	
	----- tons/acre ^a -----			
0	1.82	1.81	2.03	1.89 a
100	1.78	1.83	1.93	1.85 a
200	1.80	1.61	2.00	1.80 a
Average	1.80	1.75	1.99	

^aMeans followed by the same letter are not significantly different ($P>0.05$).
Means are averaged across tillage treatments.

Table 3. Effect of nitrogen fertilization on species composition at the Guerrieri site in 1998 .

Vegetative Component	Nitrogen Added (lbs/acre)		
	0	100	200
	----- % ^a -----		
Meadow Foxtail	26 a	34 b	37 b
Wheatgrass	13 a	16 b	21 c
Bluegrass	42 c	35 b	32 a
Clover	5 a	2 a	2 a
Sedge	7 b	6 b	4 a
Others	8 b	5 a	5 a

^aMeans within rows followed by the same letter are not significantly different ($P>0.05$).
Means are averaged across tillage treatments and application years.

Table 4. Effect of nitrogen fertilization on species composition at the Spann site in 1998.

Vegetative Component	Nitrogen Added (lbs/acre)		
	0	100	200
	----- % ^a -----		
Meadow Foxtail*	73 a	85 b	90 c
Clover*	10 b	3 a	2 a
Rush*	11 b	6 a	5 a
Others	6 b	5 b	3 a

^aMeans within rows followed by the same letter are not significantly different ($P>0.05$).
Means are averaged across tillage treatments and application years.

*Application year x nitrogen rate interaction was significant ($P<0.05$, See Table 5).

Table 5. Effect of nitrogen and years since application on species composition of meadow foxtail, clover and rush at the Spann site in 1998.

Nitrogen Added lbs/acre	Year Nitrogen was Last Applied		
	1995	1996	1997
	----- % Meadow Foxtail ^a -----		
0	75 ab	71 a	72 a
100	81 bc	83 cd	93 ef
200	83 bc	89 de	98 f
	----- % Clover ^a -----		
0	11 e	10 de	10 de
100	7 cd	3 ab	0 a
200	5 bc	1 a	0 a
	----- % Rush ^a -----		
0	10 cde	11 de	12 e
100	7 bc	7 bc	4 ab
200	8 bcd	6 ab	1 a

^a Means within vegetation group followed by the same letter are not significantly different ($P>0.05$). Means are averaged across tillage treatments.

EFFECT OF INITIAL HARVEST DATE AND NITROGEN FERTILIZATION ON YIELD AND QUALITY OF MOUNTAIN MEADOW HAY AND REGROWTH

Joe E. Brummer and N. Don Rill

SUMMARY AND RECOMMENDATIONS

Initial harvest date and nitrogen fertilization were investigated as possible management practices for manipulating the quantity and quality of regrowth from mountain meadows. Initial yields increased from 420 lbs/acre on June 15 to 3,750 lbs/acre on August 10. Crude protein content and digestibility of the hay decreased by 7 and 18 percentage points, respectively, over the same time period. Regrowth harvested in the fall decreased from a high of 3,360 lbs/acre (initial date of June 1) to a low of 130 lbs/acre (initial date of August 10). Averaged over the six initial harvest dates, yields decreased from 1,900 to 1,770 lbs/acre between October 1 and November 15. Application of 60 lbs N/acre following the initial harvest increased fall regrowth about 600 lbs/acre when averaged across all initial dates. To obtain enough regrowth to either harvest or graze, it appears that the initial harvest should be taken between July 1 and 15. This study will be continued for several more years to encompass environmental variability.

INTRODUCTION AND OBJECTIVES

Timing of initial harvest and nitrogen fertilization can be used as management tools to manipulate quantity and quality of meadow regrowth. Depending on the amount of regrowth obtained, it can either be cut for hay or grazed by cows and/or calves in the fall. There are numerous advantages to weaning calves earlier in the fall, but producers need a high quality feed in order to maintain calf gains. The objective of this study was to evaluate the effect of initial harvest date in conjunction with nitrogen fertilization on yield and quality of meadow regrowth. This database of information can be used by producers to evaluate various management practices, but the main purpose was to evaluate practices to develop high quality fall pastures for grazing by calves.

MATERIALS AND METHODS

This study was conducted approximately 6.5 miles north of Gunnison, Colorado on the Trampe Ranch. A fairly uniform area measuring 60 by 336 ft was delineated in a meadow dominated by common meadow foxtail. Red and alsike clover, Kentucky bluegrass, and various sedges were also present. Treatments consisted of 6 initial harvest dates (June 1, 15, and 29; July 13 and 27; and August 10) plus a control which was not harvested until fall. Each harvest date was then split into 3 subplots measuring 16 by 20 ft. Following the initial harvest of hay, either 0, 30, or 60 lbs/acre of nitrogen was applied to a subplot using ammonium nitrate (34-0-0). The control was fertilized on May 19, 1999 when the plots were established. Plots were harvested using a walk-behind sickle-bar mower with a 42 in. cutting width and a 3 in. cutter-bar height.

Forage was cut, tarped, and weighed and a subsample was taken for moisture and quality determinations.

In the fall, each subplot was again split into 4 sub-subplots. Each sub-subplot was assigned a fall harvest date of either October 1, October 15, November 1, or November 15. These sub-subplots were harvested as above.

The experimental design was a randomized complete block with 3 replications. Data for the initial harvest were analyzed using analysis of variance for a randomized complete block design. Data for fall regrowth were analyzed using analysis of variance for a split-split plot treatment structure within a randomized complete block design. Means were separated using the LSMEANS procedure in SAS with significance declared at the $p \leq 0.05$ level unless otherwise noted.

RESULTS AND DISCUSSION

No measurable forage was harvested on the initial date of June 1. By June 15, an average of 420 lbs/acre of high quality hay was harvested (Table 1). Hay yields continued to increase significantly as the season progressed. However, rate of growth had slowed considerably by late July with no measurable difference in yield detected between the July 27 and August 10 harvest dates.

The typical tradeoff between yield and quality of hay was observed for the initial harvests. Both crude protein content and digestibility of the hay were extremely high on the June 15 date (Table 1). A 25% drop in crude protein content was measured between the June 15 and 29 harvest dates. Crude protein content dropped only another 2.2 percentage points between June 29 and August 10. Digestibility of the hay dropped 13.7 percentage points between June 15 and July 13 during the rapid growth period typical for mountain meadows. Rate of decline in digestibility slowed after July 13 dropping only another 4.3 percentage points to about 60% by August 10. Both crude protein content and digestibility of the hay were still quite high on August 10 which was a reflection of the high clover composition at this site.

The effect of initial harvest date on amount of regrowth harvested in the fall was significant (Table 2). There were no differences in fall yields between the uncut control and June 1 harvest date. Although the June 1 plots were mowed, there was not enough forage to even gather and weigh. Therefore, differences would not have been expected. Regrowth decreased steadily from the initial harvest date of June 1 through the rest of the season and was, for all practical purposes, non-existent relative to the August 10 harvest date.

To obtain enough regrowth to either harvest or graze, it appears that the initial harvest should be taken between July 1 and 15. Although quality of the regrowth has not yet been determined, field observations would suggest that harvesting between these dates would provide the best trade-off between quantity and quality. Total seasonal yield (initial plus regrowth) was maximized by initially harvesting at the end of July (4,150 lbs/acre).

Averaged across initial harvest dates, nitrogen applied at 60 lbs/acre resulted in an extra 590 lbs/acre of regrowth (Table 3). The 30 lb/acre rate resulted in only 230 extra pounds of regrowth per acre which was not different from the control where no extra nitrogen was applied. Averaging across dates does hide some of the responses, especially for the earlier initial harvest dates. For example, 1,220 lbs/acre of extra regrowth was produced by applying 60 lbs/acre of

nitrogen when the initial harvest date was June 15. The 30 lb/acre rate of nitrogen yielded an extra 580 lbs/acre of regrowth for the same initial date. The relative response was the same for all dates because the initial harvest date by nitrogen fertilization interaction was not significant. All that changed was the magnitude of the response which decreased with successively later initial harvest dates.

Fall harvest date did not affect amount of regrowth present on any date to any great degree (Table 4). This indicated that there was little deterioration of the forage occurring over the 45 day measurement period. However, by November 15, there was an indication that the standing forage was beginning to deteriorate and disappear as there was about a 200 lb/acre decrease in yield on this date compared to the other 3. Visually, the regrowth had dried substantially between November 1 and 15. There was very little green leaf material present close to the soil surface on November 15 as compared to the other 3 dates. Although yields declined very little between October 1 and November 15, quality of the regrowth is expected to have dropped significantly. This assumption will be quantified as soon as the quality analyses are completed.

ACKNOWLEDGEMENTS

Appreciation is expressed to Bill Trampe, Gunnison Rancher, for his support of this project, use of his land, and his efforts in irrigating the plots.

Table 1. Effect of harvest date on yield, crude protein (CP) content, and in vitro dry matter digestibility (IVDMD) of mountain meadow hay cut in 1999.

Harvest Date	Yield ¹	CP	IVDMD
	lbs/acre	%	%
June 15	420 a	19.5 c	78.1 d
June 29	1480 b	14.7 b	72.2 c
July 13	2210 c	13.9 ab	64.4 b
July 27	3410 d	12.8 ab	62.4 ab
August 10	3750 d	12.5 a	60.1 a

¹Means in the same column followed by the same letter are not significantly different at the $p \leq 0.05$ level.

Table 2. Effect of initial harvest date on yield of mountain meadow regrowth cut in the fall of 1999.

Initial Harvest Date	Yield ^{2,3}
	lb/acre
Control ¹	3310 e
June 1	3360 e
June 15	2750 d
June 29	2130 c
July 13	1070 b
July 27	740 b
August 10	130 a

¹The control was not cut until fall.

²Yield were averaged over 4 fall harvest date (Oct. 1, 15 and Nov. 1, 15).

³Means followed by the same letter are not significantly different at the $p \leq 0.05$ level.

Table 3. Effect of nitrogen rate on yield of mountain meadow regrowth cut in the fall of 1999.

Nitrogen Rate ¹	Yield ^{2,3}
lbs/acre	lbs/acre
0	1650 a
30	1880 ab
60	2240 b

¹Nitrogen was applied as ammonium nitrate (34-0-0) at time of initial harvest.

²Yields are averaged over 6 initial harvest dates and the uncut control plus 4 fall harvest dates.

³Means followed by the same letter are not significantly different at the $p \leq 0.07$ level.

Table 4. Effect of harvest date on yield of mountain meadow regrowth cut in the fall of 1999.

Harvest Date	Yield ^{1,2}
	lbs/acre
October 1	1900 ab
October 15	1980 b
November 1	2060 b
November 15	1770 a

¹Yields are averaged over 6 initial harvest dates and the uncut control plus the 3 nitrogen rates.

²Means followed by the same letter are not significantly different at the $p \leq 0.05$ level.

SOIL TEST BASED FERTILIZER RECOMMENDATIONS FOR MOUNTAIN MEADOWS

A. Wayne Cooley and Jessica G. Davis

SUMMARY AND RECOMMENDATIONS

We compared standard fertilizer practices of several farmers with Colorado State University's fertilizer recommendations (based on soil testing) in three mountain meadows. Soil sampling and following CSU's fertilizer recommendations had no statistically significant impact on hay yield, although CSU's recommendations tended to have higher yields (from 440 lbs/acre up to 2,300 lbs/acre higher) and higher returns (from \$6.00 to \$30.00/acre). The innate variability in mountain meadows makes research challenging. More replicates are needed in such variable fields in order to accomplish statistical significance. However, soil testing tended to increase both yield and profit, and CSU's fertilizer recommendations appear to be sound.

INTRODUCTION

Many farmers on the West Slope do not have confidence in Colorado State University's fertilizer recommendations because they feel they were developed for conditions on the eastern plains. The purpose of this study was to evaluate CSU's fertilizer recommendations for mountain meadows in the Tri-River Area. It is of critical importance that fertilizer recommendations in the Tri-River Area be economically sound so that production is not limited by soil fertility and money is not wasted on unnecessary fertilizers which can potentially pollute water bodies that are already suffering from high salt and selenium levels.

MATERIALS AND METHODS

We did three sets of research plots in the Ridgway area in 1998 and 1999 to evaluate the soundness of CSU's fertilizer recommendations for mountain meadows. The plots were done on-farm with large plots that could be fertilized and harvested with normal size farm equipment. In each case, comparisons were made between the farmer's standard practice and CSU's recommendations based on soil testing.

Adams Ranch (1998)

Soil samples were taken on May 8, 1998 (Table 1), and urea (46-0-0) and mono-ammonium phosphate (11-52-0) fertilizers were applied on May 20, 1998 (Table 2). Plots were 80 feet wide by 625 feet long, and there were two replicates in a randomized complete block design. The plots were cut in 26.5 foot swaths on August 24, 1998 and baled on August 31, 1998.

Wolf Cattle Company (1998)

Soil samples were taken (Table 3), and ammonium nitrate (34-0-0) and mono-ammonium phosphate (11-52-0) fertilizers were applied on April 28 and 29, 1998 (Table 4). Plots were 90

feet wide by 600 feet long, and there were four replicates in a randomized complete block design. The plots were cut in 31 foot swaths and baled on August 13, 1998.

Wolf Cattle Company (1999)

Soil samples were taken (Table 5), and ammonium nitrate (34-0-0) and mono-ammonium phosphate (11-52-0) fertilizers were applied on April 27, 1999 (Table 6). Plots were 60 feet wide and ranged from 538 to 773 feet long, and there were four replicates in a randomized complete block design. The plots were cut in 35 foot swaths on July 1, 1999.

RESULTS AND DISCUSSION

Adams Ranch (1998)

The plots fertilized following CSU's recommendations produced over a ton more per acre than the unfertilized "standard" treatment (Table 7). However, due to a small number of replications (two) and lack of uniformity in the field due to flood irrigation, this yield difference was not significant. On the other hand, the economics show an increase in return by \$30/acre.

Wolf Cattle Company (1998)

The plots fertilized following CSU's recommendations were modified by the farmer as seen in Table 4. Nonetheless, CSU's modified recommendations produced about 450 lbs more per acre than the farmer's "standard" treatment (Table 8). However, this yield difference was not significant. If the treatment had been CSU's actual (unmodified) recommendation as shown in Table 4, the impact on yield may have been higher. On the other hand, the economics show an increase in return by \$17/acre.

Wolf Cattle Company (1999)

There were no statistical differences in yields among the fertilizer treatments (Table 9). However, the CSU recommendation tended to yield more (500 lbs/acre more) than the farmer's standard practice. In mountain meadows, it is difficult to find enough uniformity to prevent large variations in yields due to the variability in irrigation amounts and the presence of different grass species.

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Table 1. Soil test results from Adams Ranch (1998).

pH	Salts	Organic matter	Nitrate-N	Phosphorus	Potassium
	mmhos/cm	%	-----ppm-----		
6.2	0.3	6.5	10	1.2	296

Table 2. Fertilizer treatments at Adams Ranch (1998).

	N	P ₂ O ₅	K ₂ O
	-----lbs/acre-----		
Standard Practice	0	0	0
CSU's Recommendations	140	80	0

Table 3. Soil test results from Wolf Cattle Company (1998).

pH	Salts	Organic matter	Nitrate-N	Phosphorus	Potassium
	mmhos/cm	%	-----ppm-----		
7.6	0.5	>8.0	4	1.5	236

Table 4. Fertilizer treatments at Wolf Cattle Company (1998).

	N	P ₂ O ₅	K ₂ O
	-----lbs/acre-----		
Standard Practice	70	0	0
CSU's Recommendations (modified by the farmer)	80 (reduced from 185)	30 (reduced from 40)	0

Table 5. Soil test results from Wolf Cattle Company (1999).

pH	Salts	Organic matter	Nitrate-N	Phosphorus	Potassium
	mmhos/cm	%	-----ppm-----		
7.8	0.4	4.3	16	0.8	166

Table 6. Fertilizer treatments at Wolf Cattle Company (1999).

	N	P ₂ O ₅	K ₂ O
	-----lbs/acre-----		
Low N (Standard Practice)	80	0	0
High N	135	0	0
High N + P (CSU's Recommendations)	135	80	0

Table 7. Yields and economics at Adams Ranch (1998).

	Yield	Hay Value ¹	Fertilizer Cost ²	Return ³
	lbs/acre	-----\$/acre-----		
Standard Practice	5063 A ⁴	\$189.84	\$0	\$189.84
CSU's Recommendations	7381 A	\$276.80	\$56.88	\$219.92

¹Hay price was \$75/ton.

²Cost was \$0.125/lb for urea and \$0.15/lb for 11-52-0.

³Return = Value minus Fertilizer Cost.

⁴Treatments with the same letter are not significantly different ($p < 0.05$) by analysis of variance.

Table 8. Yields and economics at Wolf Cattle Company (1998).

	Yield	Hay Value ¹	Fertilizer Cost ²	Return ³
	lbs/acre	-----\$/acre-----		
Standard Practice	5677 A ⁴	\$283.83	\$24.68	\$259.15
CSU's Recommendations	6123 A	\$306.16	\$29.70	\$276.46

¹Hay price was \$100/ton.

²Cost was \$0.105/lb for ammonium nitrate and \$0.15/lb for 11-52-0.

³Return = Value minus Fertilizer Cost.

⁴Treatments with the same letter are not significantly different ($p < 0.05$) by analysis of variance.

Table 9. Yields and economics at Wolf Cattle Company (1999).

	Yield	Hay Value ¹	Fertilizer Cost ²	Return ³
	lbs/acre	-----\$/acre-----		
Low N (Standard Practice)	4771 A ⁴	\$202.76	\$38.70	\$164.06
High N	4363 A	\$185.42	\$22.91	\$162.51
High N + P (CSU's Recommendations)	5279 A	\$224.35	\$53.52	\$170.83

¹Hay price was \$100/ton.

²Cost was \$0.0975/lb for ammonium nitrate and \$0.1425/lb for 11-52-0.

³Return = Value minus Fertilizer Cost.

⁴Treatments with the same letter are not significantly different ($p < 0.05$) by analysis of variance.

CONSUMPTIVE WATER USE IN MOUNTAIN MEADOWS, UPPER GUNNISON RIVER BASIN, CO

Darcy G. Temple, Dan H. Smith, Joe E. Brummer, and Grant E. Cardon

SUMMARY AND RECOMMENDATIONS

Water managers need crop consumptive water use estimates to manage the competing demands of agriculture, population growth, and wildlife. The Blaney-Criddle method estimates consumptive water use based on mean monthly temperature data, percentage of daylight hours during the period of interest, and a standard crop growth stage coefficient that describes changes in consumptive water use as plants mature. In high-altitude mountain meadows, however, accurate estimates of consumptive water use can only be obtained by using locally calibrated crop coefficients. In this study field measurements of consumptive water use were made at eight irrigated meadow sites in the upper Gunnison River basin from May through September 1999. Temperature, irrigation requirement and rainfall were tabulated monthly and for the season. The data were used to derive monthly and seasonal Blaney-Criddle crop coefficients specific to the upper Gunnison River basin. The locally-calibrated coefficients for June, July, and September were considerably larger than standard coefficients for pasture grasses (2.14, 1.20, and 1.24, Gunnison River basin, vs. 0.92, 0.92, and 0.87, standard). Use of the standard coefficients would have consistently underestimated total consumptive use by 30 to 130% in June, July, and September in the Gunnison Basin. These preliminary data indicate that locally-calibrated crop coefficients are necessary to accurately predict consumptive use. To take yearly environmental variation into account, water use will be measured for an additional three to five years. This technique is applicable to meadows in other high altitude basins where water use estimates are needed.

INTRODUCTION

The Upper Gunnison River Water Conservancy District requires consumptive water use estimates to quantify irrigation depletions that would benefit from the Aspinall Unit subordination contract. The widely-used Blaney-Criddle prediction method estimates consumptive water use based on mean monthly temperature data, percentage of daylight hours during the period of interest, and a crop growth stage coefficient that describes changes in consumptive water use as plants mature. Accurate estimates of consumptive use are routinely made on Colorado's eastern plains, where a network of weather stations provides temperature and rainfall data, and the standard crop growth stage coefficients are applicable. In high-altitude mountain meadows, however, predictions are more difficult. Environmental conditions are more variable, yet weather stations are more widely scattered. The standard crop growth stage coefficients that work so well for prediction in lower altitudes underestimate consumptive use at higher altitudes. There is a clear need for prediction tools designed for high altitude areas, where much of the change in water management is occurring.

The objectives of this study were to measure consumptive water use and temperature at eight irrigated meadow sites, and to apply those measurements to the Blaney-Criddle equation to determine locally-calibrated monthly and seasonal crop coefficients for the Gunnison River basin. The locally-calibrated coefficients may then be used to predict local water use more accurately.

RESEARCH SITE LOCATIONS

The upper Gunnison River basin covers an area of about 3,000 square miles (1,920,000 acres) of which 65,000 acres were in irrigated meadow and pasture in 1998 (Colorado River Decision Support System, 1999). The majority of the irrigated meadows exist in five valleys: the mainstem of the Gunnison River, Ohio Creek, Slate/East River, Quartz Creek, and Tomichi Creek. Environmental conditions vary greatly in these valleys. Peak-to-peak valley width, ranging from three to seventeen miles, influences rainfall as well as various elements of the microclimate. Growing season length and dates of irrigation, grazing, and harvest are affected by elevation which varies from 7900' to 8700'. Soils consist of glacial outwash deposited in floodplains and alluvial fans and range from cobbly sands to gravelly loams to clays (Table 1). Water available for crops depends on soil type and location relative to the river. Meadows at river level typically have high water tables year round. Other meadows, situated on terraces up to 50 feet above modern river level (the result of river cutting since the last glaciation), have water tables that vary widely with season and require irrigation for summer maintenance.

The diversity of the upper Gunnison River basin environment suggests that a wide range of consumptive water use values might be expected. Sites were selected in each of the major hay-producing valleys to fully evaluate the different environments within the Gunnison basin.

MATERIALS AND METHODS

A compensating lysimeter (1 m² by 30 in. deep) was installed at each site between April 21 and May 18, 1999. The lysimeter was placed in an excavated hole, leveled carefully, and filled with a four-inch layer of gravel. The lysimeter was refilled with the excavated soil layers, replacing each layer in the approximate order that it was removed. The original sod (6 in.) was then replaced so that the lysimeter lip rose approximately three inches above the sod surface. Adjacent to the lysimeter, an 8 in. diameter by 30 in. deep PVC tank with float valve was installed to supply water to the base of the lysimeter. The float tank was replenished by gravity feed from a 12 in. diameter, 5-foot deep PVC reservoir. A two-inch diameter PVC access tube placed in one corner of the tank allowed monitoring of the lysimeter water table. A similar observation well was placed in the meadow three feet from each lysimeter to observe the field water table. A continuously-recording temperature logger and rain gauge were placed at each lysimeter site. In July, an automated weather station was installed at the Gunnison River site to provide information on wind run, relative humidity, and solar radiation as well as temperature.

Temperature recorders were activated between 7 May and 25 May, 1999. Float valves in the four lysimeters on river-level sites (labeled 'shallow' in Table 1) were set to maintain the water table four inches below the soil surface. In the remaining four lysimeters, the water table was maintained eight inches below the soil surface. Water was added to the lysimeters, float tanks,

and reservoirs, and the lysimeters were allowed to equilibrate until the water table measured in the lysimeter's access tube equaled the float valve depth. Equilibration of all lysimeters was accomplished by 25 May at which time water use measurements were begun.

Twice-weekly site visits were made to record data and refill the reservoirs. At each visit, lysimeter water use (water withdrawn by evaporation and transpiration) was measured by recording the drop in water level in the reservoir. Lysimeter water tables were monitored through the access tube to assure proper functioning of the system. Field water table and precipitation were recorded and the temperature data were downloaded. Degree of settling of the lysimeter soil, lysimeter vegetation height, density and variety, field vegetation height, density, and variety, and surface soil wetness in the field and the lysimeter were also noted. Dates of irrigation initiation and cessation were also observed and recorded.

Irrigation began between 6 May and 24 May on all sites except the Ohio Creek (high) site where it began 28 May. Due to the wildflooding employed by most ranchers, the water table was at or near the soil surface during periods of irrigation. In June, fields around all sites except the Slate/East River and Gunnison River sites had standing water for part or all of the month. The surface soil of all lysimeters remained damp throughout this period.

Plants re-established rapidly in the lysimeters at most sites, and developed a mix of vegetation similar to surrounding fields. In late June, an infrared thermometer was used to test the lysimeters for plant stress. Canopy temperatures within lysimeters were equal to temperatures of surrounding vegetation, and no stress was observed.

Field irrigation was terminated on six of eight sites between July 12 and August 1. The Ohio Creek (high) field water was shut off earlier (24 June), and the Slate/East River field was irrigated until September 15. Field water tables remained shallow until about 30 July, due to heavy rainfall, and then dropped rapidly. Lysimeter water tables were lowered on 30 July to a depth of 22 inches to simulate the end of irrigation and the subsequent drop of the field water table. The Slate/East River lysimeter water table was not lowered until August 13; field irrigation continued at that site throughout August.

Under optimal growing conditions, operators cease irrigating in mid-July to early August. The field soils begin to dry, and harvesting occurs throughout late July and August. However, frequent rains throughout July and August delayed the haying season in 1999. Five sites were hayed between 13 August and 26 August, and the remaining three sites were not cut until mid-to-late September. Lysimeter vegetation was clipped to a height of three inches at approximately the same time that the surrounding field was harvested to maintain water use comparable to field water use. Clippings were retained to determine yield by weight and species distribution.

Data were collected until 30 September at which time the reservoirs, rain gauges, and temperature sensors were disassembled and stored for the winter. In mid September, two additional lysimeters were installed. A 30 in.-deep lysimeter was installed 1000 ft. south of the original Gunnison River site on a more productive portion of the field. The upper Tomichi Creek (high) site received a 48 in.-deep lysimeter. This paired lysimeter configuration will allow improved simulation of the lowering of the field water table after irrigation is reduced and then stopped. An additional shallow and deep lysimeter pair will be installed in the spring at a site to be determined.

To calculate locally calibrated crop coefficients, this study determined actual consumptive water use. Actual consumptive water use is the sum of the measured irrigation water

requirement and effective rainfall. The measured irrigation water requirement was determined by measuring the amount of water withdrawn from the lysimeter reservoir by evaporation and crop transpiration. Effective rainfall is the percentage of measured rainfall that infiltrates to the root zone and is usable by the crop.

Crop growth stage coefficients were calculated from actual consumptive water use, mean monthly temperature, and percentage of daylight hours for various selected intervals of the growing season (usually on a monthly basis). The following paragraphs describe calculations used to determine irrigation requirement, total consumptive use, and Blaney-Criddle crop growth stage coefficients.

Determination of irrigation requirement and total consumptive use:

Irrigation requirement (inches) = Lysimeter reservoir use (inches) x .06996 inches ET per inch reservoir use.

Effective rainfall (inches) = measured rainfall x percentage effective precipitation. Effective rainfall includes that rainfall which infiltrates into the soil to, but not past, the rooting depth. Rain which evaporates before infiltrating or runs off the surface is excluded.

Effective precipitation was assumed to be 75% for June, July, and September and 80% for August (Colorado Irrigation Guide, 1988, Table CO683.50(m), Estimated seasonal and monthly consumptive use of crops, Gunnison, Colorado).

Total consumptive use = Irrigation requirement (inches) + Effective rainfall (inches).

Determination of Blaney-Criddle crop growth stage coefficients:

Temperature calculations: Daily mean temperature, the average of maximum and minimum daily temperatures, was calculated for each site. Monthly mean temperatures were determined for each site, and averaged for each month. (Table 2).

Percentage of daylight hours: This parameter was interpolated from Table 1, Irrigation Water Requirements, (USDA SCS, 1970).

The Blaney-Criddle method:

The SCS Blaney-Criddle equation for consumptive use is of the form $U = k * f$

where: U = monthly consumptive use (inches)

k = an empirical consumptive-use crop coefficient for a month

$= k_t * k_c$

where: $k_t = 0.0173t - 0.314$

k_c = crop growth stage coefficient, obtained from tables
or derived from measured consumptive use

f = the monthly consumptive use factor = $(t * p)/100$

where: t = mean monthly air temperature ($^{\circ}\text{F}$)

p = monthly percentage of daylight hours in the year
at a given latitude

To derive specific crop coefficients for the upper Gunnison River basin, use measured total monthly consumptive use to obtain:

$$k_c = (100 * U) / (k_t * t * p) = (100 * U) / ((0.0173t - .314) * t * p)$$

RESULTS

Seasonal trends in total consumptive use, irrigation requirement, and effective rainfall were determined. Total consumptive use (Table 3) and irrigation requirement (Table 4) were summed for each site monthly and seasonally, and averaged for all sites. For the period June 1 to September 30, 1999, total consumptive water use (irrigation requirement plus effective rainfall) averaged 17.1 in. (range 12.5 to 20.2 in.) with variation attributed to site-specific environmental factors. Consumptive use averaged over eight sites was 6.34 in. during June, 5.16 in. during July, and 11.49 in. for the two-month period of June and July. These values are higher than the estimated average monthly consumptive use for pasture grasses in Gunnison (June, 3.46 in.; July, 4.44 in.) reported in the Colorado Irrigation Guide (1988).

In June and July, 1999, the lysimeter water tables were set 4 in. or 8 in. below the surface to simulate full irrigation. Measured irrigation requirement averaged over eight sites was 6.27 in. during June, 3.97 in. during July, and 10.24 in. for the two-month period of June and July (Table 4). Lysimeter irrigation requirements measured in August and September, 1999 using a water table 22 in. below the soil surface may be less representative of actual field conditions. Water tables in the field were observed to drop two to five feet below the base of the lysimeter in many locations in August and September. This disparity in water available to plants within the lysimeter as compared to the field was partially mitigated by the continued frequent rainfall in August.

Calculated crop coefficients

The crop growth stage coefficient was calculated monthly for each site and for the average of all sites (Table 5). As noted above, most lysimeters were configured to simulate the end of irrigation on July 30, 1999. Simulated full irrigation continued until August 19, 1999 at Slate/East River site. To take advantage of this additional data, a partial-month coefficient was calculated for the period August 1 to August 19, 1999 for that site only.

The eight-site averages of the monthly coefficients were as follows: June, 2.14; July, 1.20; August, 0.86; September 1.24. Seasonal coefficients were calculated for three periods: two months (June and July), three months (June, July and August), and four months (June, July, August and September). Additional years of data are needed to take yearly environmental variation into account.

DISCUSSION

High crop growth stage coefficients in June reflected the rapidly maturing native grasses, increasing temperatures and high total consumptive use. June irrigation water use, in turn, was high in response to high levels of consumptive use and low rainfall. July's lower crop growth stage coefficients and lower irrigation water use were probably influenced by lower evaporation resulting from lower maximum temperatures and higher rainfall, respectively. Note, however, that all sites continued to use more water than was supplied by rainfall.

Lysimeter water tables were lowered at the end of July to simulate cessation of irrigation and lysimeters were harvested in mid-August. In August, rainfall decreased in volume but occurred

almost daily, and average maximum temperature increased. Total consumptive use and irrigation requirement decreased in August.

CONCLUSIONS

Since irrigation ceased by the end of July and crop harvest began on many fields by 15 August, the June and July crop coefficients will most closely reflect irrigation water use in the Gunnison basin during the growing season.

Table 5 compares the calculated coefficients to the original coefficients derived for use with pasture grasses (USDA SCS, 1970). The published coefficients for pasture grasses in June, July, August, and September are 0.92, 0.92, 0.91, and 0.87, respectively. These are considerably smaller than coefficients determined in this study for June, July, and September (2.14, 1.20, and 1.24, respectively), and approximately equal to August (0.86). Use of the published coefficients would have consistently underestimated total consumptive use by 30 to 130% in June, July, and September in the Gunnison basin.

Although additional years of data are needed to take yearly environmental variation into account, these preliminary data indicate that published crop coefficients should be replaced by locally calibrated crop coefficients to ensure a more accurate prediction of consumptive use of irrigation water.

LITERATURE CITED

- USDA Soil Conservation Service. 1970. Irrigation water requirements. Engineering Division, Technical Release No. 21, U.S. Government Printing Office. 87 p.
- USDA Soil Conservation Service. 1975. Soil survey of Gunnison area, Colorado. USDA Soil Conservation Service, Washington, D. C. 83 pp.
- USDA Soil Conservation Service. 1988. Colorado Irrigation Guide. USDA SCS, Denver.

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Table 1. Descriptions of 8 sites in the upper Gunnison River basin where consumptive water use was measured in 1999.

Site	Location	Elev. (ft)	Unirrigated Water Table	Soil description (organic mat thickness/ surface soil type/subsoil type/drainage classification)
Eagle Ridge	Ohio Creek low	8110	shallow	3 in. o.m./clay loam /cobbly clay loam >24 in./well drained
Irby (lower)	U. Tomichi Creek low	8110	shallow	4 in. o.m./calcareous loam /clay loam /well drained
Irby (upper)	U. Tomichi Creek high	8135	deep	3 in. o.m./loam /cobbly sandy clay loam /cobbly loam /well drained
Lost Miner	L. Tomichi Creek	7775	shallow	4 in. o.m./loam /gravelly loam /poorly drained
McClain	Quartz Creek	8340	shallow	4 in. o.m./loam /gravelly loam /poorly drained
Miller	Ohio Creek high	8260	deep	3 in. o.m./clay loam /calcareous loam /well drained
Spann	Slate/East River	8690	deep	4 in. o.m./cobbly sandy loam /very cobbly sandy loam/well drained
Trampe	Gunnison River	7900	deep	3 in. o.m./red sandy loam /cobbly sandy loam >8 in./well drained

Table 2. Mean monthly temperature for 8 sites within the upper Gunnison River basin over 4 months during 1999. Monthly mean temperature at each site is the average of daily mean temperatures at each site. Daily mean temperature is the average of the daily maximum and minimum temperature at each site.

Month	Site								Average
	Slate/ East River	Ohio Creek (high)	Ohio Creek (low)	Upper Gunnison River	Quartz Creek	Lower Tomichi Creek	Upper Tomichi Creek (low)	Upper Tomichi Creek (high)	
June	49.0	50.6	51.6	52.5	52.6	53.0	52.1	50.6	51.5
July	57.3	58.4	59.3	60.4	60.2	61.2	60.2	59.4	59.6
August	54.9	56.3	57.0	57.8	57.6	58.7	57.0	56.2	56.9
Sept	45.2	47.7	47.2	48.0	49.0	48.8	47.1	45.8	47.4
Average	51.6	53.3	53.8	54.7	54.9	55.4	54.1	53.0	53.8

Table 3. Total consumptive use (irrigation requirement plus effective rainfall, inches) for 8 sites within the upper Gunnison River basin over 4 months during 1999.

Site									
Month	Slate/ East River	Ohio Creek (high)	Ohio Creek (low)	Upper Gunnison River	Quartz Creek	Lower Tomichi Creek	Upper Tomichi Creek (low)	Upper Tomichi Creek (high)	Average
Lysimeter water table set at 4 in. or 8 in. below soil surface to simulate full irrigation									
June	5.94	6.39	6.3	5.23	6.47	7.53	5.62	7.23	6.34
Jul	5.11	6.03	5.97	4.90	5.48	5.14	3.86	4.75	5.16
2 mo. Total	11.05	12.42	12.27	10.13	11.95	12.67	9.48	11.98	11.49
Lysimeter water table set at 22 in. below soil surface to simulate no irrigation									
Aug	2.66	4.94	2.93	3.97	2.88	2.66	1.97	2.77	3.10
Sep	1.94	2.88	1.73	4.38	3.40	2.23	1.03	2.48	2.51
4 mo. Total	15.65	20.24	16.93	18.48	18.23	17.56	12.48	17.23	17.10

Table 4. Irrigation requirement, in inches, for 8 sites within the upper Gunnison River basin over four months during 1999.

Month	Site								Average
	Slate/ East River	Ohio Creek (high)	Ohio Creek (low)	Upper Gunnison River	Quartz Creek	Lower Tomichi Creek	Upper Tomichi Creek (low)	Upper Tomichi Creek (high)	
Jun	Lysimeter water table set at 4 in. or 8 in. below soil surface to simulate full irrigation								
Jul	5.41	5.80	5.70	4.73	6.25	7.12	5.05	6.55	5.83
2 mo. Total	3.19	3.83	3.68	2.71	3.67	2.96	1.67	2.64	3.04
2 mo. Total	8.60	9.63	9.38	7.44	9.92	10.08	6.72	9.19	8.87
Aug	Lysimeter water table set at 22 in. below soil surface to simulate no irrigation								
Sep	1.07 ¹	2.52	0.44	2.46	1.45	0.13	0.35	1.58	1.25
2 mo. Total	0.69	1.96	0.83	3.59	2.87	1.42	0.54	2.07	1.75
2 mo. Total	1.76	4.48	1.27	6.05	4.32	1.55	0.89	3.65	3.00
4 mo. Total	10.36	14.11	10.65	13.49	14.24	11.63	7.61	12.84	11.87

¹Water table set at 22 in. on 13 Aug, 1999

Table 5. Blaney Criddle crop growth stage coefficient (k_c) for 8 sites within the upper Gunnison River basin over 4 months during 1999. Seasonal coefficients were calculated for three periods: two months (June and July), three months (June, July and August), and four months (June, July, August and September).

Period	Site								Average of Sites	Published ² Pasture Grass k _c
	Slate/ East River	Ohio Creek (high)	Ohio Creek (low)	Upper Gunnison River	Quartz Creek	Lower Tomichi Creek	Upper Tomichi Creek (low)	Upper Tomichi Creek (high)		
Monthly Coefficient¹										
June	2.27	2.25	2.11	1.68	2.06	2.35	1.84	2.55	2.14	0.92
July	1.30	1.46	1.40	1.09	1.23	1.11	0.87	1.11	1.20	0.92
Lysimeter water table lowered at most sites on 30 July, 1999 ¹										
August	0.80	1.40	0.80	1.05	0.77	0.68	0.54	0.79	0.86	0.91
September	1.09	1.41	0.87	2.11	1.55	1.03	0.52	1.35	1.24	0.87
Partial month Coefficient										
Aug 1-19	0.92									
Seasonal Coefficient										
2mo (JJ)	1.69	1.78	1.69	1.33	1.58	1.62	1.26	1.68	1.58	--
3mo (JJA)	1.39	1.65	1.39	1.24	1.31	1.30	1.03	1.39	1.34	--
4mo (JJAS)	1.34	1.61	1.31	1.38	1.35	1.26	0.95	0.01	1.15	--

¹Lysimeter irrigation ceased on 19 August, 1999 at Slate/East River site. A partial-month coefficient was calculated for the period 1 August to 19 August, 1999 for that site only.

²USDA Technical Release 21, 1970.