Level Benches for Forage Production in the Northern Plains

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Abstract

Level benches 4- and 8-m-wide were constructed at the Wyoming Agriculture Research and Extension Center, Gillette, Wyoming 1970. Replicated benches and controls were seeded with Ladak alfalfa, Nordan crested wheatgrass, intermediate wheatgrass, and mixtures of Ladak alfalfa and crested and intermediate wheatgrass. Phosphorus (134 kg P_2O_5/ha) was applied to all benches and to the control. Ammonium nitrate was applied at 90 kg N/ha in May 1972 and 1977, and at 45 kg/ha in April 1974 to the benches and control, except those seeded to alfalfa alone. Snow trapped in the benches was not uniformly distributed because of the benches' northeast orientation. However, more soil water was available for plant use. The deep-rooted alfalfa was compatible with the shallow-rooted crested wheatgrass and seemed the best combination tested for forage production on level benches in northeast Wyoming. Construction of level benches is a practice that can ensure a dependable source of quality feed by trapping and holding snow for onsite use. Forage yields from the benches and the controls varied with years. During the 8 years (1970–1978) on the 4- and 8-m-wide benches, alfalfa yields averaged 3,420 and 3,813 kg/ha, respectively, and alfalfa and crested wheatgrass mixture averaged 3,560 and 3,855 kg/ha, respectively. Crested wheatgrass alone on 4- and 8-m-wide benches averaged 2,569 and 2,456 kg/ha, respectively, and on the 4- and 8-m-wide control averaged 2,382 and 2,786 kg/ha, respectively. Intermediate wheatgrass on the 4- and 8-m-wide benches averaged 2,329 and 3,425 kg/ha, respectively, and on the 4- and 8-m-wide controls averaged 2,565 and 3,262 kg/ha, respectively. Grass yields did not differ significantly when grasses were grown alone on the benches or on the control.

In the Northern Plains, snow can fall anytime from September through May and, occasionally, during the summer at higher elevations. Generally, snow is maximum in late fall and late spring. Variation in water content of snow is related to the volume of drier snow received during the winter as compared with the volume of wetter snow received during the spring or fall (Grebb 1975).

Generally, snowfall over an area tends to be more uniform than rainfall; thus, snowmelt can be a more dependable source of surface water. Properly managed, snow is a resource with high potential for Great Plains agriculture. When snow is not managed as a resource, snowmelt runoff is lost and can contribute to erosion and downstream flooding. The water available for seed germination and seedling emergence from properly managed snowmelt at the beginning of a growing season could be more valuable than the same amount of water later in the season.

Land-surface modifications, like contour furrows and level benches, are practices used for trapping and holding snow, reducing snowmelt runoff, and increasing soil water for plant use. Level benches differ from conventional terraces because their channels are wider. They are level in all directions and uniformly distribute collected and stored water for crop production from both snowmelt and torrential rains (Fig. 1). They are diked in their

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Fig. 1. *Eight-meter-wide level benches holding snow.*

ends and the downslope side to give them more water-storage capacity.

Black and Siddoway (1975) found that trapping and holding snow with tall wheatgrass *(Agropyron elongatum)* barriers had much promise for increasing soil-water supplies with the additional bonus of controlled wind erosion in eastern Montana. Haas and Willis (1968) reported that smooth bromegrass *(Bromus inermis)* on the dikes of level benches was effective in trapping snow in North Dakota (Fig. 2).

In south central North Dakota, level benches increased water storage and doubled alfalfa *(Medicago sativa)* and smooth bromegrass yields as compared with those on adjacent sloping lands (Haas et al. 1966; Haas and Willis 1967, 1968). McMartin et al. (1970a) stated that using level benches would be economical for growing alfalfa for a cash crop for livestock feed. Net return for alfalfa from benches on 1 and 2% slopes without contributing areas ranged from $900 to 1300/.40 ha (McMartin et al. 1970b). They

Fig. 2. *Crested wheatgrass barrier on the dikes in late summer.*

calculated these returns, assuming the price of alfalfa was $19/MT.

Cost and construction of level benches will vary with soil type, topography, and geographic locations. Since these benches are essentially permanent, construction costs can be prorated over several years. To efficiently harvest benches, their width should be some multiple of the harvesting machinery used.

If benches are to be grazed, we recommend that grazing be deferred 2 to 3 years so the grass can become established and the dikes settled to minimize damage by livestock. Growing a small grain crop on the benches the first year would provide organic matter and stubble for holding snow and a good seedbed for grasses and alfalfa to be seeded.

The purpose of this study was to determine the feasibility of increasing forage production in northeastern Wyoming by managing snow with level benches with a northeastern exposure.

Materials and Methods

The University of Wyoming Agricultural Research and Extension Center is located in northeastern Wyoming about 3 km east of Gillette. Elevation is 3,189 m and topography is rolling to gently rolling plains. The experimental area had a northeastern exposure with the original slope (before benching) ranging from 2% on the tail slope to nearly 15% on the head slope. The area had been previously seeded to crested wheatgrass *(Agropyron desertorum)* and alfalfa and used for hay production. Soils on the experimental area were not uniform. Fort Collins loam (fine-loamy, mixed, mesic Ustollic Haplargids) occupied about 20% of the lower portion of the tail slope. Olney fine sandy loam (fine-loamy mixed, mesic Ustollic Haplargids) was above the Fort Collins and occupied 20% of the experimental area. The upper portion of the area occupying the 6 to 15% slope was Cushman loam and Terry sandy loam (fine-loamy and coarse-loamy, mixed, mesic family of Ustollic Haplargids, respectively, with inclusions of Shingle clay loam (loamy, mixed, (calcareous) mesic, shallow Ustic Torriorthenths) Olney and Fort Collins. The Fort Collins loam, Olney fine sandy loam, Cushman loam and Terry sandy loam all belong to the same family. The Cushman and the Terry sandy loam are moderately deep, whereas, the other two are deep soils. Thus, they are similar agronomically except for depth.

Table 1. Average monthly snow accumulation, precipitation, maximum and minimum temperatures, and wind velocity at the Research and Extension Center, Gillette, Wyoming.

	Snow depth[1] (cm)	Precipitation[1] (mm)	Temperature Max °C	Temperature Min° C	Wind[2] (km/hr)
January	25.6	14	-1.7	-13.3	10.3
February	25.4	15	3.3	-8.3	9.2
March	26.7	19	6.7	-6.1	10.2
April	26.1	51	12.8	-1.7	9.9
May	5.3	62	18.9	3.3	8.5
June	0.5	88	25.0	8.9	6.3
July	—	35	30.0	11.1	5.7
August	—	29	30.0	11.1	6.1
September	2.5	32	23.9	5.0	6.4
October	9.4	30	14.4	0.0	6.5
November	20.6	18	6.7	-6.1	7.5
December	30.7	14	0.6	-10.6	8.8
Total	172.8	407	14.2	-0.6	7.9

[1]Average 22 years (1956-1977).
[2]Average 10 years (1968-1977).

Northeastern Wyoming has a semiarid-temperate climate with wide variations in precipitation, temperature, and with abrupt changes in weather. Average (1950 to 1977) annual and seasonal (April 1 to September 30) precipitation, recorded at the Agricultural Research and Extension Center, was 384 and 271 mm,

Table 2. Average monthly snow accumulation (S), cm; precipitation (P), mm; and wind (W), km/day; during winter (1971-1978) at the Gillette Substation, Wyoming.

Year		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	Total
1971	S	54.6	26.4	13.5	45.0	47.2	46.0	16.0	2.5	251.2
	P	77	21	10	27	30	31	63	77	336
	W	177	204	246	225	233	230	216	187	1718
1972	S	27.7	2.3	36.6	26.7	24.6	26.9	11.4	2.5	158.7
	P	30	6	15	15	13	36	34	46	195
	W	127	122	193	257	236	232	235	219	1621
1973	S	37.1	15.7	20.6	24.1	8.1	43.9	59.7	—	209.2
	P	78	10	19	12	2	35	82	26	264
	W	174	217	201	290	177	240	245	212	1756
1974	S	3.0	9.6	19.3	33.0	22.3	17.3	16.5	—	121.0
	P	57	14	10	22	11	15	75	39	243
	W	140	143	142	282	261	294	240	240	1742
1975	S	20.6	42.2	34.0	20.8	16.8	30.7	47.7	27.4	240.2
	P	27	25	18	14	8	22	76	92	282
	W	158	153	216	174	220	257	224	179	1581
1976	S	7.1	31.2	23.4	22.9	14.7	20.1	11.9	—	131.3
	P	22	21	8	16	8	15	53	68	211
	W	119	167	241	228	241	209	224	175	1604
1977	S	5.6	26.9	40.4	54.3	30.7	63.0	8.1	—	229.0
	P	62	19	25	28	25	40	21	53	273
	W	142	198	199	224	216	273	183	182	1617
1978	S	T	60.4	52.1	25.9	37.6	8.4	12.9	27.9	225.2
	P	10	37	30	16	27	10	58	281	469
	W	—	—	—	—	—	—	—	—	—
Mean	S	19.5	26.8	30.0	31.6	25.2	32.0	23.0	4.4	198.5
	P	45	19	17	19	15	25	58	85	283
	W	148	172	205	240	226	248	224	199	1662

Table 3. Herbage yields (kg/ha) at 12% moisture for 1971 through 1978 from a 4-m-wide level benches at Gillette Wyoming.

Year	Alfalfa		Crested wheatgrass		Intermediate wheatgrass		Alfalfa and crested wheatgrass		Alfalfa and intermediate wheatgrass	
	Bench	Control[1]	Bench	Control	Bench	Control[1]	Bench	Control	Bench	Control
1971	4203	2714	2856	2956	2098	2411	3858	2912	2836	2514
1972	3388	2437	3073	2960	3071	2215	3765	2850	3125	2257
1973	2849	927	1159	1456	1382	1370	2884	1576	1743	1543
1974	3494	3212	2651	3110	2415	3745	3810	2885	5091	3441
1975	4422	3534	2900	2597	2197	3170	4096	3362	3569	3368
1976	2725	1483	2175	1764	2258	1874	2905	1798	1986	2425
1977	3658	1896	2724	2064	2657	2212	3613	2083	2656	2212
1978	2620	3622	3017	2148	2557	3518	3550	2173	2863	4232
Mean	3420[a2]	2478[b]	2569[a]	2382[a]	2329[a]	2654[a]	3560[a]	2455[b]	2999[a]	2749[a]

[1]Total herbage yields includes cheatgrass.
[2]Means between bench and controls for a given forage treatment followed by same letters are not significantly different at the 5% level according to Duncan's multiple range test.

respectively. Beginning in 1956, snow depth was measured after each storm. Table 1 lists snow depths and precipitation measurements for 1956 to 1977 and temperatures and hourly wind velocities for 1968 to 1977.

Winter precipitation (October 1 through March 31) averaged 110 mm or 27% of the average (1956–1977) annual precipitation. From 1971 to 1977, the winter snow-depth accumulation averaged 165.2 cm or 26.8 cm more than the 22-year average (Table 2). From 1968 to 1977, January had the highest average wind velocities, followed by those for March, April, February, and December (Table 1). The frost-free period (1931–1977) averaged 126 days and mean annual temperature was 7°C. Temperature extremes have ranged from 42° to −40°C over the 47 years of record. The prevailing wind direction was northwest. Average May-through-September (1968-1977) evaporation from a standard weather bureau evaporation pan was 1,194 mm.

Level benches were constructed in April 1970 with a road patrol. The topsoil was stockpiled upslope and redistributed on the completed benches (Fig. 3). Ten benches were 8 m wide on the lower slopes (1 to 6%) and 10 benches were 4 m wide on the steeper slopes (6 to 15%). The 8-m-wide benches averaged 107 m long and the 4-m-wide benches averaged 60 m long. Control plots' lengths averaged 30 m, with an average width of 10 m. Benches have a northeastern exposure and the prevailing winds are from the northwest. Natural topography does not always allow positioning the benches perpendicular to the prevailing winds.

The contiguous control area was disk plowed in early May 1970. In late May before seeding, the benches and control area were tandem disced and spike tooth harrowed. Replicated benches and control were drill seeded with Ladak alfalfa, Nordan crested wheatgrass, and intermediate wheatgrass *(Agropyron intermedium)* at 4.5, 11.2, and 11.2 kg/ha bulk seed, respectively. A mixture of alfalfa and crested wheatgrass and alfalfa and intermediate wheatgrass was seeded at 2.2 and 4.5 kg/ha bulk seed, respectively, on May 30, 1970. The alfalfa seed was not inoculated. The dikes on the benches were hand seeded with alfalfa and intermediate wheatgrass and firmed with a cultipacker.

Before seeding, phosphorus was applied to all benches and to the control area at the rate of 134 kg P_2O_5/ha. The benches and the control area, except those seeded to alfalfa alone, were fertilized with ammonium nitrate at 90 kg N/ha on May 12, 1971 and 1977, and at 45 kg/ha on April 24, 1974.

Alfalfa plants became established on the benches seeded to grass alone from residual plants and seed blown in from the alfalfa plants on the dikes even though these benches were sprayed with 2,4-D (2,4-dichlorophenoxy) acetic acid initially on June 10, 1971, and again on May 15, 1973, and May 23, 1974. The alfalfa was vigorous and seemed similar in amount to that on the benches seeded to alfalfa, intermediate wheatgrass, and to the alfalfa-intermediate wheatgrass mixture.

Overwinter gain in soil water was determined gravimetrically to the 1.5-m depth at 30-cm-depth increments by sampling the 8-m-wide benches and controls before freezing (in September or October) and after spring thaw (about mid-May). The difference in soil-water content of the spring and fall sampling was considered the over-winter gain of soil water. We did not sample soil water on the 4-m control area because of the steep slope.

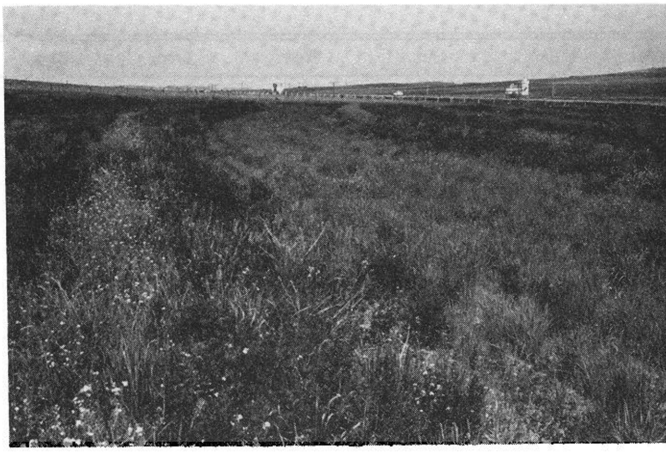

Fig. 3. *A 8-m-wide bench of intermediate wheatgrass. The dark plant material on the dikes and in the benches is alfalfa.*

Table 4. Average herbage yields (kg/ha) at 12% moisture obtained from cut and along the dike areas of the 4-m wide benches, cut, center, and along the dike areas of the 8-m wide benches at Gillette, Wyoming, for 1971 through 1978.

Treatment	4-m-wide benches		8-m-wide benches		
	Cut	Dike	Cut	Center	Dike
Alfalfa	2972[b]	3867[a]	3483[b]	3606[a]	4357[a1]
Crested wheatgrass	2393[a]	2745[a]	1932[b]	2602[ab]	2834[a]
Intermediate wheatgrass	2253[b]	2723[a]	3521[a]	3745[a]	3920[a]
Alfalfa and crested wheatgrass	3361[a]	3760[a]	3808[a]	3992[a]	3765[a]
Alfalfa and intermediate wheatgrass	2729[b]	3241[a]	2072[b]	2360[ab]	2868[a]

[1]Means within a treatment and bench width followed by the same letters are not significantly different at the 5% level according to Duncan's multiple range test.

Table 5. Herbage yields (kg/ha) at 12% moisture for 1971 through 1978 from 8-m-wide level benches at Gillette, Wyoming.

	Alfalfa		Crested wheatgrass		Intermediate wheatgrass		Alfalfa and crested wheatgrass		Alfalfa and intermediate wheatgrass	
Year	Bench	Control[1]	Bench	Control	Bench	Control[1]	Bench	Control	Bench	Control
					kg/ha					
1971	3820	3295	2818	4088	3108	3923	3621	3032	2424	2849
1972	3379	3039	2865	3463	3879	3209	3980	3194	2923	3080
1973	3179	1886	1515	2073	2080	1426	2762	1818	1443	1594
1974	4097	3544	2331	2290	2422	3753	4290	3663	2421	2480
1975	5336	5208	2215	2976	5234	3887	4566	3317	2554	2965
1976	2759	2799	1885	1945	2835	2230	2695	2449	1768	1856
1977	3573	2563	2427	2207	3511	2347	4019	3099	2775	2627
1978	4378	4253	3592	3249	4331	5320	4909	4108	3162	2879
Mean	3815[a2]	3323[b]	2456[a]	2786[a]	3425[a]	3262[a]	3855[a]	3085[b]	2434[a]	2541[a]

[1]Total herbage yields includes cheatgrass.
[2]Means between bench and control for a given forage treatment followed by same letter are not statistically different at the 5% level according to Duncan's multiple range test.

Hay yields were determined during the last week of June from nine 6.1-m by 0.9-m swaths taken with a Jari[1] mower from each of the 8-m-wide benches (three swaths each along the dikes, center of bench, and cut area) and four swaths on the 4-m-wide benches (two swaths each along the dikes and cut area). Two swaths were taken from the central portion of each plot on the control. Herbage yields were determined by oven drying samples at 70° C for 24 hours and actual hay production was calculated on 12% moisture basis. To determine the amount of cheatgrass *(Bromus tectorum)* present in the alfalfa treatment on the control area, six 0.18-m² plots were located in the alfalfa control plots and the vegetation was clipped to ground level and separated by species.

Herbage yields were analyzed by analysis of variance. Overwinter gain in soil water was analyzed by analysis of variance and "*t*" test. Duncan's multiple range test was to compare means value for significance.

Results and Discussion

Herbage yield

4-m-wide benches

A good stand of grasses and alfalfa was obtained on all the benches, dikes, and controls from a late May planting in 1970. Herbage yields from the benches and the controls varied with years and N application. Applying N appears to have increased the herbage yields during the years of application (1971, 1974, and 1977) and the next years (Table 3 and 5). The overall average total herbage yields from the 4-m-wide benches seeded to alfalfa and the alfalfa-crested wheatgrass mixture were significantly higher than their controls (Table 3). There was no significant differences in the average total herbage yields for the grasses seeded alone on the benches or on the controls. Herbage yields from the crested wheatgrass and alfalfa mixture grown on the benches average 1,105 kg/ha more than the control, whereas, the alfalfa and intermediate wheatgrass mixture grown on the benches averaged 1,105 kg/ha more than the control, whereas, the alfalfa and intermediate wheatgrass mixture grown on the benches averaged only 250 kg/ha more than the control over the 8-year period (1971-1978).

The 4-m-wide benches seeded to alfalfa, intermediate wheatgrass, and to the alfalfa-intermediate wheatgrass mixture produced significantly more total herbage along on the dikes than on the cut side (Table 4). There were no significant differences in yields of crested wheatgrass or alfalfa-crested wheatgrass mixtures along the dikes or the cut side of the benches.

Table 6. Overwinter (October to May 15, 1971-1977) gain of soil water (mm) in top 1.5 m of soil for the 8-m-wide control and for the 4-m-wide and 8-m-wide level benches at Gillette, Wyoming.

Treatment	71-72	72-73	73-74	74-75	75-76	76-77	Treatment mean
			8-m-wide benches control				
			mm				
Alfalfa		42.6	62.5	105.4	117.3	80.3	81.6[a2]
Crested wheatgrass		43.9	80.5	104.6	108.7	46.7	76.9[a]
Intermediate wheatgrass		39.6	66.0	66.8	89.4	95.0	71.4[a]
Alfalfa + crested wheatgrass		20.8	52.8	97.8	75.9	80.3	65.5[a]
Alfalfa + intermediate wheatgrass		31.7	74.4	119.4	65.5	86.4	75.5[a]
Avg.		35.7[c]	67.2[b]	98.8[a]	91.4[ab]	77.7[ab]	
			4-m-wide benches				
Alfalfa	39.4	144.5	146.0	208.8			134.7[a]
Crested wheatgrass	42.7	138.4	117.6	170.7			117.3[a]
Intermediate wheatgrass	52.6	157.2	80.8	160.8			112.8[a]
Alfalfa + crested wheatgrass	25.9	129.0	131.3	186.4			118.1[a]
Alfalfa + intermediate wheatgrass	35.3	157.0	95.2	138.2			106.4[a]
Avg.	39.1[c]	145.2[a]	114.2[b]	173.0[a]			
			8-m-wide benches				
Alfalfa	50.3	173.2	108.4	152.9	108.7	112.0	117.6[a]
Crested wheatgrass	59.2	149.3	96.8	149.9	121.4	121.9	116.4[a]
Intermediate wheatgrass	50.3	196.8	81.3	156.5	135.4	115.6	122.6[a]
Alfalfa + crested wheatgrass	46.2	164.1	112.0	181.6	77.0	113.5	115.7[a]
Alfalfa + intermediate wheatgrass	74.4	176.5	96.5	172.2	87.4	90.9	116.3[a]
Avg.	56.1[c]	172.0[a]	99.0[b]	162.6[a]	106.0[b]	110.8[b]	

[1]Means among treatments and years followed by the same letter are not significantly different at the 5% level, according to Duncan's multiple range test.

Table 7. Comparison of overwinter (October 1 to May 15, 1972 through 1977) gain (mm of soil water in 1.5 m of soil) for the 8-m-wide control and 8-m-wide benches at Gillette, Wyoming.

	Alfalfa		Crested wheatgrass		Intermediate wheatgrass		Alfalfa and crested wheatgrass		Alfalfa and intermediate wheatgrass	
Year	Bench	Control	Bench	Control	Bench	Control	Bench	Control	Bench	Control
1972-73	173.2	42.6	149.3	43.9	196.8	39.6	164.5	20.8	176.5	31.7
1973-74	108.4	62.5	96.8	80.5	81.3	66.0	112.0	52.8	96.5	74.4
1974-75	152.9	105.4	149.9	104.6	156.5	66.8	181.6	97.8	172.2	119.4
1975-76	108.7	117.3	121.4	108.7	135.4	89.4	77.0	75.9	87.4	65.5
1976-77	112.0	80.3	121.9	46.7	115.6	95.0	113.5	80.3	90.9	86.4
Mean	117.6[a1]	81.6[b]	116.4[a]	76.9[b]	122.6[a]	71.4[b]	115.7[a]	65.5[b]	110.8[a]	75.5[b]

[1]Means within a forage treatment followed by the same letter are not statistically different at the 5% level according to the "t" test.

8-m-wide benches

Mean total herbage yields for the alfalfa and for the alfalfa and crested wheatgrass mixture on the 8-m-wide benches were significantly greater than those for their control (Table 5). Intermediate wheatgrass controls contained much more cheatgrass than did the crested wheatgrass controls which, may account for the higher yields as compared with those for the crested wheatgrass controls. Total herbage yields differed significantly among years for the benches and for the controls.

The benches seeded to alfalfa, crested wheatgrass, and to the alfalfa-intermediate wheatgrass mixture produced significantly more total herbage along the dikes than on the cut sides (Table 4). Except for the alfalfa treatment, there were no significant differences among the herbage yields between the center portion and the cut sides of the benches.

In summarizing the 4- and 8-m-wide benches, the data indicate that the average total herbage yields obtained from the 4- and 8-m-wide benches for alfalfa, crested wheatgrass, and for the alfalfa-crested wheatgrass mixtures did not differ significantly. Average total yields from the 8-m-wide benches seeded to intermediate wheatgrass were significantly greater than that from the 4-m-wide benches, perhaps because of the amount of alfalfa present in the 8-m wide benches than in the 4-m wide benches.

Although alfalfa plants that became established on the benches seeded to grass alone were sprayed with 2,4-D in 1971, 1973, and 1974, new plants soon reestablished on these benches. The grasses are shallow-rooted where alfalfa has a taproot adapted to obtaining water from greater depths. Thus, crested wheatgrass was also an invader on those plots where it was not seeded. Crested wheatgrass on the 4-m-wide dikes died out either because the roots were eaten by ground squirrels *(Citellus tridecemlinentus)*, or they were dried. These dikes were sandier than those on the 8-m-wide benches and the coarser texture would have allowed faster drying. Cheatgrass, a shallow rooted annual, invaded on the controls and on some of the dikes. Some of the dikes on the 4-m-wide benches also were affected by ground squirrels. These aerated and dried portions of the dikes.

Cheatgrass

Cheatgrass was abundant from 1972 through 1978 in the control plots seeded to alfalfa, intermediate wheatgrass, and the intermediate wheatgrass-alfalfa mixture. In 1973 and 1974, cheatgrass accounted for 71 and 80%, respectively, of the total herbage on the alfalfa control plots and the alfalfa was severely stunted. During the next 4-years (1975 through 1978) cheatgrass accounted for 30, 81, 39, and 50% of the total herbage on the alfalfa control plots. Again, in the years of dense cheatgrass infestations, the alfalfa was stunted and yields were depressed. When cheatgrass was less abundant, alfalfa yields were higher.

We did not determine the amounts of cheatgrass on the controls seeded to intermediate wheatgrass and to intermediate wheatgrass-alfalfa mixture. We estimated that the amount of cheatgrass present on the controls seeded to intermediate wheatgrass with or without alfalfa resembled that found on the control alfalfa plots. Herbage was of higher quality on the benches because there was less cheatgrass and other undesirable plants (Fig. 3).

Overwinter Soil Moisture

Generally, snow began to accumulate on the benches in late October and continued through April (Table 2). Much of January snow was relocated by wind since it was the windiest month, followed by March (Table 2). Snow from spring storms from the southeast was generally well distributed on the benches and not relocated since spring snow is wetter than winter snow. Because benches were not oriented perpendicular to the prevailing winds (northwest), most of the trapped snow accumulated along the dikes and extended outward into the bench. This provided a large amount of snow for onsite use by forage.

Overwinter (October 1 through mid-May) snow accumulations from 1972 through 1977 ranged from 121.0 to 240.3 cm (Table 2). Average soil water within the 1.5-m soil depth for the same 5-years (1972–77) ranged from 14.6 to 136.3 mm more on the 8-m-wide benches than on the 8-m-wide controls.

Samples for the soil water were collected to the 1.5-m depth at 30-cm depth increment on the 8-m-wide benches and controls in the fall and in mid May. No significant differences were found for the amounts of soil water for forage treatments on the 8-m-wide and the 4-m-wide benches, but we did find significant differences in the amounts of soil water among years (Table 6).

Average overwinter snow accumulation (1971–1978) was 14% greater for the first three months (January, February, and March) than for the last 3 months (October, November, and December). Average April–May precipitation was nearly the same as the average total winter precipitation for the same 1971–78 period.

From 1972 through 1977, all benches had significantly more soil water at the 1.5-m soil depth than did the control (Table 7). Differences in overwinter gain of soil water from the 3-years (1972–1975) ranged from 70 to 30% more soil water at the 1.5-m soil depth on the 4-m benches than on the control.

The control area did not benefit as much from the overwinter snow. Snow cover was generally light and was readily evaporated, because revegetation was short and did not trap the snow. Overwinter gain in soil water on the control was mainly from wet snows during October and April and from May precipitation.

Summary

The most efficient orientation for benches is perpendicular to the prevailing winds, but natural topography may not always allow this orientation. In our study, benches and controls were on northeast exposure oriented parallel with prevailing winds (northwest). Thus, trapped snow was not uniformly distributed on the benches, but collected on back and in front of the dikes. Even though the benches were not as efficient in trapping snow, this study showed they were worthwhile as additional water from trapped snow was obtained in the benches.

Level benches can be used as a practice to ensure a dependable source of alfalfa. The alfalfa and the crested wheatgrass mixture seem to be most compatible and the best combination for the northern plains, because alfalfa is deep rooted, and grasses are shallow rooted.

Regrowth in the benches was sufficient most years for grazing. Two cuttings of alfalfa or the alfalfa-grass mixture are possible in some years. Three cuttings of alfalfa were obtained from benches oriented perpendicular to the prevailing winds in North Dakota (Wayne O. Willis, personal communication).

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