Fertilization of Seeded Grasses on Mountainous Rangelands in Northeastern Utah and Southeastern Idaho[1]

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Fertilization has been widely tested as a way to increase herbage production of western rangelands. Eckert *et al.* (1961) found a response to nitrogen in the eight to 12-inch precipitation zone in Nevada, but concluded that fertilization would not be practical. In North Dakota, with 17 inches of precipitation, Rogler and Lorenz (1957) obtained an average of 2,271 pounds of air-dry herbage per acre per year from a heavily grazed native pasture when they applied 90 pounds of nitrogen per acre for six successive years. Unfertilized range yielded 748 pounds per acre. Two years of fertilization did more to improve the range than six years of complete isolation from grazing.

On Colorado's Front Range McGinnies (1962) worked on five sites with precipitation of 12 to 16 inches. He found that nitrogen increased herbage yields on older seeded grass stands on average or better sites and in years of average or above-average precipitation. Eckert and Bleak (1960) determined that four mountain soils with 15 to 40 inches annual precipitation in western Nevada and northern California were deficient in nitrogen, phosphorus, and lime. Retzer (1954) obtained no important increase in native herbage by top dressing with 14 fertilizers and minor elements on seven range soils on sites with 15 to 30 inches of precipitation in the Rocky Mountains.

Gomm (1962) worked in a high-altitude park in Montana, where the annual precipitation was 25 inches. He found that fertilizers probably decreased the number of established seedlings. Hull *et al.* (1962) applied several fertilizers spring and fall for three years on new range seedings on six mountainous areas in the West where precipitation ranged from 12 to 40 inches annually. They found that nitrogen increased seedling numbers at one location and increased vigor of seeded and native plants at most locations.

On many dry ranges where moisture limits plant growth and on some mountainous areas where precipitation is high, fertilization has given erratic results. The present studies were initiated to test the response of seeded grasses on mountainous rangelands to commercial fertilizers.

FIGURE 1. General view of the Logan Canyon area where fertilizers were applied in 1957 and 1958.

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Experimental Procedures and Results

This paper reports three studies separately: (1) Fertilization of pubescent wheatgrass (*Agropyron trichophorum* (Link) Richt.) in northeastern Utah, (2) Fertilization of new seedings in southeastern Idaho, and (3) Fertilization of a mixture in southeastern Idaho.

Nitrogen (N) was appplied as ammonium nitrate and phosphorus (available P_2O_5) as treble superphosphate on the soil surface. Results were measured by numbers of plants per square foot or by pounds of air-dry herbage per acre. Chemical content of the herbage was determined in the third study. Soil and herbage samples were analyzed by standard procedures. Significance of results at the five-percent level was determined by Duncan's (1955) multiple range test.

Fertilization of Pubescent Wheatgrass in Northeastern Utah

The experimental area was a big sagebrush (*Artemisia tridentata* Nutt.) covered opening in the spruce (*Picea* spp.) and fir (*Abies* spp.) zone at an elevation of 7,700 feet in Logan Canyon (Figure 1). Aspect was southwest with a 15-percent slope. Nearby snow survey and summer precipitation records showed an annual precipitation of approximately 32 inches; 4.5 inches of rain June to September and 27.5 inches of late fall rain and winter snow. Snow usually covered the area from mid-November to mid-May. The soil was a loam Soil characteristics at the zero to six and six to 12-inch depths before treatment were as follows (data for the shallow depth are listed first): pH (saturated paste) 6.3, 6.5; percent soluble salts 0.02, 0.02; organic matter percent 6.9, 4.1, nitrogen percent 0.3, 0.2; and pounds P_2O_5 per acre 390, 241.

Pubescent wheatgrass was seeded in the fall of 1953. A good stand of grass resulted. Three replicates of six fertilizer treatments listed below were applied to one series of plots in October 1957 and to another series in June 1958.

Results: Rates of fertilizer (pounds per acre) applied both spring and fall and average air-dry grass production (pounds per acre) in 1958 were: No fertilizer, 760; N 20, 685; N 40, 718; N 60, 842; N 40 and P_2O_5, 200 791; and P_2O_5 200, 811. Although fertilizers were associated with increased grass yields, the differences were not significant. There was no significant difference between spring and fall application. Favorable moisture in 1959 caused yields which were almost double those in 1958, but again there was no significant difference in grass growth or yield. There were no visible differences either year in season of growth, color, or vigor of the grass as the result of fertilizer treatments.

Fertilization of New Seedings in Southeastern Idaho

The study area was a weedy opening at 8400 feet elevation in the spruce-fir type in Franklin Basin, southeastern Idaho. The aspect was west with a three-percent slope. Snow normally covered the area from late October to June 1. Five-year snow survey and summer precipitation records averaged 42.3 inches annually. Winter snow and late-fall rain amounted to 36.2 inches; rain from June to September 6.1 inches. The first 12 inches of soil were a silt loam with clay loam below. Calcium carbonate at all depths was 0.2 percent (Table 1).

Ten seeding methods were used in the fall and three in the spring with four replications for three years (1957-1960). The following species were seeded separately in each seeding method; intermediate wheatgrass (*Agropyron intermedium* (Host) Beauv.), slender wheatgrass (*A. trachycalum* (Link) Malte), pubescent wheatgrass, smooth brome (*Bromus inermis* Leyss.), and hard fescue (*Festuca ovina* var. *duriuscula* (L.) Koch).

Five fertilizer treatments were applied at right angles to all seeded rows at the following pounds per acre at the time of seeding: (1) No fertilizer; (2) N 100; (3) P_2O_5 200; (4) N 100 and P_2O_5 200; and (5) N 100, P_2O_5 200, potash (K_2O) 100, sulfur (S) 100, copper sulfate 50, ferrous sulfate 50, magnesium sulfate 50, manganous sulfate 50, zinc sulfate 50, sodium borate 20, and ammonium molybdate one pound per acre.

Seedlings were counted spring and fall for three years after seeding. Notes were made on height and vigor of seeded and native species.

Results: Averaging all five species on all seeding treatments gave the following plants per square foot for the five fertilizer treatments listed above: 0.8, 0.7, 0.7, 0.6, 0.6. Fertilizer application did not significantly affect plant

Table 1. Soil characteristics at Franklin Basin before fertilizers were applied.

Soil depth	pH	Salts	Potassium	P_2O_5	N	Organic matter	Moisture percent 15	⅓	Saturation
(Inches)	(Saturated paste)	(EC x 10^3)	(me/100 g.)	(lb/A)	(Percent)		(Atmospheres)		
0-3	5.9	.26	1.04	66	.20	3.9	11	29	45
3-6	5.9	.22	.72	49	.20	3.8	11	28	48
6-12	5.7	.18	.62	—	.15	3.0	12	27	47
12-24	5.6	.21	.58	—	.11	2.0	12	26	44
24-36	5.5	.19	.45	—	.06	.9	9	22	38

FIGURE 2. The grass mixture on the left was seeded in 1957 and fertilizers were applied October 1960, and May 1961. Unseeded area on the right supports mainly tarweed *(Madia glomerata* Hook.)

numbers. There were no differences in emergence, survival, vigor, or color of seeded or native plants.

Soil samples were taken to 24 inches in June and September 1960 on areas fertilized the third year (fall of 1959 and spring of 1960). Nitrogen applied at 100 pounds in the fall or in the spring did not increase soil nitrogen. Two hundred pounds of P_2O_5 applied in the fall or in the spring significantly increased the phosphorus in the top six inches of soil (Table 2). Soil nitrogen and phosphorus between 12 and 24 inches were similar to the six to 12-inch depth and are not shown.

Lime was applied at five tons per acre in 1959 and 1960 to see whether it would increase the effectiveness of the fertilizer. Lime changed the pH of the topsoil from 5.9 to 6.8 but did not affect the growth of seeded or native plants.

Fertilization of a Seeded Mixture in Southeastern Idaho

This study also was carried out in Franklin Basin on the same site as study two (Table 1). The area was seeded in 1957 to a mixture (Figure 2.) In 1960 species comprised the sward in percentage of the stand as follows: Timothy *(Phleum pratense* L.) 35, smooth brome 20, meadow foxtail *(Alopecurus pratensis* L.) 18, tall oatgrass *(Arrhenatherum elatius* (L.) Presl) 18, orchard grass *(Dactylis glomerata* L.) five, and intermediate wheatgrass four.

Fertilizers were applied on the seeded mixture October 25, 1960, and May 30, 1961, with three replications (Table 3). To determine where the fertilizers were going, soil samples were taken to a depth of 42 inches in June and August, 1961 (Table 4). The soil was deep, but because of rockiness it was difficult to get soil samples below 42 inches. Soil properties below 24 inches were similar to those at the 12- to 24- inch depth; therefore, the greater depths were omitted from Table 4.

Results: When nitrogen was applied at 200 or 600 pounds per acre and nitrogen at 200 pounds with 200 pounds of phosphorus in the spring or in the fall it made no significant difference in herbage yield, but significantly increased the nitrogen and pro-

Table 2. Nitrogen and phosphorus in the soil sampled June 10 and September 9, 1960, resulting from fertilizer applied October 15, 1959, and June 5, 1960.

Application and sampling month	Soil[1] depth	Nitrogen		P_2O_5	
		No N	N 100	No P_2O_5	P_2O_5 200
	(Inches)	— — (Percent) — —		(Pounds per acre)	
October application					
June sampling	0-3	.17	.18	64	115
	3-6	.16	.17	62	105
	6-12	.18	.16	75	86
September sampling	0-3	.17	.16	81	291
	3-6	.15	.17	66	123
	6-12	.13	.17	35	63
June application					
September sampling	0-3	.16	.13	72	282
	3-6	.15	.11	56	86
	6-12	.13	.15	37	35

[1]Results from samples below 12 inches are not shown.

tein contents of the herbage (Table 5). The results for protein were similar to those for nitrogen and are not shown.

Nitrogen applied at 100, 200, and 600 pounds per acre in October was not in the soil as nitrate nitrogen the following June. Nitrogen applied in May was found only in the top six inches of soil in August. Soil nitrogen from the 100-pound rate was not significantly greater than the check. The 200-pound rate and 200 pounds plus 200 pounds of P_2O_5 per acre caused a significant increase over the 100-pound rate. The 600-pound rate gave a significant increase over the 200-pound rate.

Phosphorus applied at 200 pounds P_2O_5 per acre in October or May did not significantly increase herbage yield or the phosphorus in the herbage, but could be measured as a significant increase in soil phosphorus in the top six inches of soil the following June and August.

The fertilized grass was classified as dark, medium, or light green (normal) color. There were wide variations but the average green color in 1961 and 1962 was as follows:

Table 3. Air-dry herbage in August 1961 and 1962 from plots fertilized in October 1960 and May 1961.[1]

Application dates and sampling	Fertilizer treatments					
	None	N 100	N 200	N 600	N 100 and P_2O_5 200	P_2O_5 200
	(Pounds per acre)					
October 1960 application						
August 1961 sampling	5159	5483	4882	5285	5487	5428
August 1962 sampling	5148	4867	4820	4961	5171	5218
May 1961 application						
August 1961 sampling	4912	4974	5329	5611	5084	4922
August 1962 sampling	5008	5007	4750	5009	5101	4961

[1] Herbage yields showed no significant differences.

Fertilizer treatment	*Applied spring*		*Applied fall*	
	1961	*1962*	*1961*	*1962*
Check	light	light	light	light
P_2O_5 200 lb/A	light	light	light	light
N 100 lb/A	medium	light	light	light
N 200 lb/A	dark	medium	medium	light
N 200 lb/A	dark	dark	dark	medium

Discussion

Nitrogen at 20 to 600 pounds per acre did not increase the herbage production significantly. Fall-applied nitrogen was probably leached away by 30- to 40-inches of water from late-fall rains and from snow melt. Complete leaching, however, is not consistent with the increased nitrogen in the herbage or with the darker green color of the fertilized grass in the mixture at Franklin Basin.

The loss of soil nitrogen from spring applications is not as easily explained. Soil samples showed that approximately 100 pounds of nitrogen from the 100- and 200-pound rates and 200 pounds from the 600-pound rate were lost by August. The greatest loss was probably by denitrification, in which nitrite or nitrate nitrogen is released as gaseous or molecular nitrogen. In an acid soil, such as that at Franklin Basin, the nitrite form or nitrous acid is unstable and may decompose by chemical action and become lost as NO. Also nitrate nitrate nitrogen is often decomposed along with organic matter and released as nitrogen gas.[2] High moisture and temperature, such as are present at Franklin Basin, speed denitrification. Fertilizers were applied on May 30, 1961. For the next two weeks the soil moisture was at field capacity or above and temperatures were moderately high. Maximum weekly temperatures in degrees Fahrenheit are given as follows:

Week ending	Soil surface	¾-inch soil depth	Air
May 29	100	81	65
June 5	100	72	62
June 12	109	90	71

Leaching of spring-applied nitrogen is a possibility. The soil moisture was at field capacity at the time of fertilization. Rainfall between then and August was 3.4 inches but as the rains did not percolate far into the soil, leaching was probably not important.

Some nitrogen loss could occur through volatilization. Studies on grassland soils show that up to 50 percent of nitrogen broadcast in the ammonium form can escape to the atmosphere.[3]

Two hundred pounds of P_2O_5 per acre approximately doubled the phosphorus in the top six inches of soil but did not increase herbage yields or phosphorus in the herbage. Enough phosphorus was available in the soil for good growth of grass; hence, additional phosphorus either went unused or instituted luxury consumption.

Soil moisture probably did not limit plant growth. If so, grass burning should have been evi-

[2] *Clark, Francis E. Nitrogen losses on grassland soils. Range Fertilization Workshop, August 22-24, 1961, Denver, Colorado. (Mimeo)*

[3] *Loc. cit. Francis E. Clark. Nitrogen losses on grassland soils.*

Table 4. Soil nitrogen and phosphorus in plots fertilized in October 1960, and May 1961. Soil samples taken June and August 1961.

Application and sampling month	Soil depth	Nitrogen					P_2O_5		
		No N	N 100	N 200	N 200 and P_2O_5 200	N 600	P_2O_5 200	N 200 and P_2O_5 200	P_2O_5 200
	(Inches)	(ppm)					(Pounds per acre)		
October application									
June sampling	0-6	7.2[ab1]	6.6[abc]	—	9.3[a]	9.1[a]	76[b]	206[a]	—
	6-12	5.6[abc]	6.0[abc]	—	7.0[ab]	6.4[abc]	37[bc]	47[bc]	—
	12-24[2]	4.0[bc]	3.7[bc]	—	4.2[bc]	4.9[bc]	26[c]	25[c]	—
August sampling	0-6	2.7[c]	2.7[c]	3.1[c]	5.7[c]	7.6[c]	89[b]	153[a]	162[a]
	6-12	1.7[c]	1.9[c]	2.2[c]	3.6[c]	3.4[c]	42[cde]	36[def]	50[cd]
	12-24	1.5[c]	1.5[c]	1.2[c]	1.3[c]	2.0[c]	33[def]	26[ef]	33[def]
May application									
August sampling	0-6	2.3[c]	7.1[c]	42.0[b]	45.5[b]	197.7[a]	83[b]	161[a]	150[a]
	6-12	2.9[c]	1.9[c]	6.7[c]	9.5[c]	12.7[c]	60[c]	55[cd]	53[cd]
	12-24	1.9[c]	1.7[c]	2.6[c]	2.3[c]	3.0[c]	36[def]	38[def]	31[def]

[1]Any two means followed by the same letter are not significantly different at the five-percent level. June and August sampling analyzed separately.
[2]Results of samples below 24 inches are not shown.

dent on the high-nitrogen plots. Soil samples to the 48-inch depth under the fertilized grass in October after fall rains had penetrated 15 inches showed adequate moisture for growth at all depths. Therefore some of the deeper roots of the grasses were probably always in soil above the wilting point.

Although applied nitrogen did not increase herbage production, it increased the nitrogen content of the herbage and caused plants to be a darker green color. Further study is needed on the utilization of nitrogen by seeded range plants and on nitrogen loss from range soils. Study is also needed on the value of high-quality protein forage on selected mountainous rangelands.

Summary

Three studies on soil fertilization of seeded grasses were carried out on mountainous rangelands.

Nitrogen at 20, 40, and 60 pounds per acre and phosphorus at 200 pounds of P_2O_5 per acre applied fall and spring on a four-year-old stand of pubescent wheatgrass did not significantly affect grass yields, growth, or color.

Nitrogen, phosphorus, potassium, sulfur, and seven minor elements were applied fall and spring for three years as seedings were made. Fertilizers did not increase stand establishment or affect the growth or color of seeded or native plants. Nitrogen at 100 pounds per acre applied in the fall or in the spring did not increase soil nitrogen the following summer. Phosphorus at 200 pounds of P_2O_5 per acre applied fall or spring increased the phosphorus in the topsoil.

Nitrogen at 100, 200, and 600 pounds, and P_2O_5 at 200 pounds per acre applied fall and spring on a four-year-old mixture of seeded grasses made no significant difference in herbage yield. Nitrogen at the high rates significantly increased the protein and nitrogen content of the herbage and caused it to turn a darker green. Nitrogen applied in the fall was not in the top 42 inches of soil the next June or August. Part of the nitrogen applied in May was still in the topsoil in August. Phosphorus applied in the fall or spring increased the phosphorus in the topsoil, but did not increase the phosphorus in the herbage.

Table 5. Nitrogen and phosphorus content of the herbage in August 1961 from plots fertilized October 1960, and June 1961.

Fertilizer treatment	Nitrogen		Phosphorus	
	Fertilized October	Fertilized May	Fertilized October	Fertilized May
(Pounds/acre)	(Percent)			
None	.8[d1]	.8[d]	.14[a]	.15[a]
N 100	1.1[cd]	1.0[cd]	—	—
N 200	1.3[c]	1.2[c]	—	—
N 600	1.4[bc]	1.8[a]	—	—
N 200 and P_2O_5 200	1.2[c]	1.6[a]	.15[a]	.17[a]
P_2O_5 200	—	—	.16[a]	.15[a]

[1]Any two means followed by the same letter are not significantly different at the five-percent level.

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