Yield, Quality, and Fertilizer Recovery of Crested Wheatgrass, Bromegrass, and Russian Wildrye as Influenced by Fertilization[1]

D. E. SMIKA, H. J. HAAS, AND G. A. ROGLER

Soil Scientists, Soil and Water Conservation Research Division, and Research Agronomist, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Mandan, North Dakota

Fertilization of grasses on the Great Plains and adjacent areas has been studied by several investigators in recent years. The literature contains numerous reports from these areas on the effect of fertilizers on yield and protein content of cultivated grasses.

Anderson, et al. (1946) reported that bromegrass herbage yields increased with increasing nitrogen rates to approximately 100 pounds of nitrogen per acre. Beyond this rate, the fertilizer became less effective in stimulating yield but more effective in increasing protein percentages. Sneva, et al. (1958) found that yields and protein content of crested wheatgrass were increased by nitrogen rates up to 30 pounds of nitrogen per acre. Stitt, et al. (1955) and Whitman, et al. (1957) reported that crested wheatgrass yields were increased by nitrogen applications up to 150 and 200 pounds of nitrogen per acre, respectively. Stitt, et al. (1955) also found that protein percentages increased with increasing nitrogen rates.

Kilcher (1958) and Stitt (1958) studying several grasses, concluded that crested wheatgrass showed the greatest response to nitrogen fertilizer with Russian wildrye responding somewhat less. Kilcher, who also used several sources of nitrogen, found that yield increases of the grasses studied were not related to nitrogen source.

The present study was conducted at the Northern Great Plains Field Station, Mandan, North Dakota. The objectives were (1) to determine which fertilizer treatments would produce highest yields, (2) to determine the effect of various fertilizer treatments on protein and phosphorus content of the forage, and (3) to determine the percentage recovery of the applied nitrogen and phosphorus.

Experimental Plan and Procedure

This study involved seven commercial fertilizer treatments (30-0-0, 30-30-0, 30-30-30, 60-0-0, 60-60-0, 60-60-60, and 90-0-0 pounds of N — P_2O_5 — K_2O per acre, respectively); one barnyard manure treatment (15 tons per acre); and one no-fertilizer treatment (0-0-0). There were two randomized replications of each. The fertilizers were broadcast annually in late fall, except in the first and fourth year, when they were broadcast in the spring. The grasses used in this study were crested wheatgrass (*Agropyron desertorum* (Fisch.) Schult.); Russian wildrye (*Elymus junceus* Fisch.); and bromegrass (*Bromus inermis* Leyss.). The sources of nitrogen and phosphorus varied during the experiment. Nitrogen sources used were sodium nitrate, ammonium sulfate, and ammonium nitrate. Phosphorus sources were superphosphate (20 percent P_2O_5) and treble superphosphate (approximately 45 percent P_2O_5). Potassium was supplied

---

[1]*Cooperative investigation of the Soil and Water Conservation Research Division and Crops Research Division, Agricultural Research Service U.S. Department of Agriculture.*

Table 1. Climatic data. Northern Great Plains Field Station, Mandan, North Dakota.

Year of study	Precipitation		Mean temperature	
	Annual	April-June	Annual	April-June
	(Inches)		(°F)	
First	16.77	6.23	43	51
Second	21.11	10.35	42	56
Third	13.71	6.33	41	54
Fourth	16.29	6.09	41	57
Fifth	19.30	7.83	36	49
Sixth	20.31	5.51	37	52
Seventh	10.25	4.71	42	57
7-year average	16.82	6.73	40	54
40-year average	15.83	6.93	41	54

as potassium chloride throughout the experiment. The grasses were spring-seeded in 6-inch rows and fair stands of all species were obtained. The plots were 7 by 12 feet in size. The study was located on soil classified as Cheyenne fine sandy loam, which had an average total nitrogen content of .116 percent in the surface six inches. Climatic data during the growing season for the period of study are presented in table 1. All three grasses were harvested on the same date, generally near the bloom stage. However, since Russian wildrye is an earlier maturing grass it was further advanced at harvest than the other two grasses. Yield data were collected during a 7-year period and the hay was analyzed for protein and phosphorus for all years except the second and third. Recovery of applied fertilizer was calculated by individual years with no consideration given to previous fertilizer applications. Yearly determinations were based on the increase in pounds of nitrogen (nitrates included) or phosphorus per acre in the hay of the various fertilizer treatments over the pounds of nitrogen or phosphorus in the non-fertilized hay.

Results and Discussion

Plants receiving either commercial fertilizers or manure produced more and larger heads than those that were not fertilized. There were also more tillers and leaves on the fertilized plants. In addition, fertilized or manured plants were deeper green in color. Height of all grasses was influenced only by nitrogen. Grass height increased as the rate of application increased up to and including the 60 pound per acre rate.

Yields

Seven year average results (table 2) show that yield increases from each fertilizer treatment were highest for crested wheatgrass followed in order by bromegrass and Russian wildrye. The application of barnyard manure produced highly significant increases in yields of all grasses. When commercial fertilizers were applied, response was largely due to nitrogen. Yields from the 30-0-0 treatment were significantly higher than from the no-fertilizer treatment and were similar to those where manure had been applied. Where 60 pounds of nitrogen alone was applied, the yields were significantly greater than those from the 30 pound rate. The 90 pound rate of nitrogen produced significantly higher yields than the 60 pound rate with Russian wildrye only. It appeared that under the conditions of this study 60 pounds of nitrogen was sufficient for maximum production of crested wheatgrass and bromegrass, but at least 90 pounds of nitrogen was required for Russian wildrye. Apparently it is essential that large quantities of available nitrogen be present for high production of Russian wildrye. Although phosphorus, in combination with nitrogen, increased yields, nearly 300 pounds in some cases, over the nitrogen alone treatment, the increases were not significant at the .05 level. Potassium, in combination with nitrogen and phosphorus, resulted in no increase in yield over that of the nitrogen-phosphorus treatment.

Quality

Information relative to the effect of manure and different rates of nitrogen phosphorus,

Table 2. Seven year average hay yields (12 percent moisture) and average increase in yields over the no fertilizer treatment for three species of grass under different fertilizer treatments.

Fertilizer treatment	Crested wheatgrass		Russian wildrye		Bromegrass	
	Yield	Average increase over ck.	Yield	Average increase over ck.	Yield	Average increase over ck.
	Pounds Per Acre					
0-0-0 (ck)	540	—	170	—	380	—
Manure	1420	880	680	510	1030	650
30- 0- 0	1560	1020	600	430	1070	690
30-30- 0	1690	1150	670	500	1210	830
30-30-30	1670	1130	690	520	1100	720
60- 0- 0	2150	1610	1240	1070	1830	1450
60-60- 0	2440	1900	1400	1230	1950	1570
60-60-60	2500	1960	1450	1280	1930	1550
90- 0- 0	2460	1920	1640	1470	1930	1550
L.S.D. .05	470	—	370	—	420	—
L.S.D. .01	620	—	500	—	560	—

Table 3. Average percentage protein and phosphorus content of hay for three species of grass under different fertilizer treatments for a 5-year period.

	Fertilizer treatments*								
	0-0-0	Manure	30-0-0	30-30-0	30-30-30	60-0-0	60-60-0	60-60-60	90-0-0
					Percent				
					Crested wheatgrass				
Protein	7.69	8.13	8.25	7.88	8.31	10.19	10.37	9.88	12.00
Phosphorus	.199	.222	.146	.183	.189	.132	.197	.197	.134
					Russian wildrye				
Protein	10.50	10.81	11.44	11.06	11.06	12.88	12.94	12.44	14.31
Phosphorus	.238	.348	.170	.244	.246	.137	.240	.235	.133
					Bromegrass				
Protein	9.25	10.13	10.56	10.25	10.00	12.63	12.31	11.75	14.19
Phosphorus	.217	.272	.173	.224	.220	.157	.250	.233	.154

*Pounds of N — P_2O_5 — K_2O per acre, respectively.

and potassium on forage quality (protein and phosphorus content) is presented in table 3.

Protein content — The manure treatment increased the percentage protein in all cases when compared to the no-fertilizer treatment, but the percentages did not equal those obtained from the 30-0-0 treatment. When nitrogen was applied alone the protein percent increased with each increase in rate of application, irrespective of grass species. Phosphorus, in combination with nitrogen, decreased the percentage protein in most cases, when compared with nitrogen alone percentages. The application of potassium in combination with nitrogen and phosphorus also decreased the protein content when compared with nitrogen alone, in all but one case.

From these results, it is apparent that the protein content of the three grasses studied was increased 4 to 5 percent by adequate nitrogen fertilizer. Russian wildrye was highest in protein content followed closely by bromegrass. Crested wheatgrass was approximately 2 percent lower in protein than bromegrass. Since Russian wildrye matures somewhat earlier than the other two, protein content of this grass would probably have been even higher if it had been harvested at the same stage of maturity as the others.

Phosphorus content — When considering percentage phosphorus, it is evident that barnyard manure increased phosphorus concentration considerably above all other treatments. On the other hand, when nitrogen alone was applied, marked decreases in percentage phosphorus were obtained. Evidently, plants could not obtain sufficient phosphorus from the soil to keep pace with the increase in growth due to nitrogen fertilizer, and the concentration of phosphorus decreased.

The application of phosphorus, in combination with nitrogen, restored the percentage phosphorus to a level slightly above that of the non-fertilized plants in most cases. The greatest increase in percentage phosphorus from commercial fertilizers resulted from the 60-60-0 treatment on bromegrass. Percentage phosphorus values of plants receiving potassium in combination with phosphorus and nitrogen were similar in most cases to those which received only phosphorus and nitrogen.

It is evident from the results that commercial fertilizers in most instances had little effect on increasing the percentage phosphorus of the grass. Barnyard manure, however, was effective in increasing phosphorus percentage, which suggests that manure applied to hay land would be beneficial in increasing the phosphorus content of hay.

Table 4. Percent recovery of applied nitrogen from different fertilizer treatments for three species of grass.

Year of study	Fertilizer treatments*						
	30-0-0	30-30-0	30-30-30	60-0-0	60-60-0	60-60-60	90-0-0
				Percent			
				Crested wheatgrass			
1st	51.2	54.1	51.1	49.5	59.7	51.5	47.6
4th	30.5	31.7	31.1	25.6	28.3	29.5	24.4
5th	44.5	60.4	74.4	59.3	85.1	78.7	73.7
6th	21.1	27.8	34.6	30.1	33.3	39.3	30.5
7th	8.1	18.3	16.1	16.6	22.5	17.4	19.6
Average	31.1	38.5	41.5	36.2	45.8	43.3	39.2
				Russian wildrye			
1st	21.2	25.6	26.5	24.5	27.5	24.6	23.1
4th	12.3	12.0	14.0	21.5	17.8	20.7	22.9
5th	29.8	35.2	36.6	46.3	54.0	60.2	48.7
6th	19.6	14.9	19.4	26.7	25.6	25.0	24.7
7th	5.8	11.8	15.8	16.8	17.6	18.1	14.7
Average	17.7	19.9	22.5	27.2	28.5	29.7	26.8
				Bromegrass			
1st	52.3	54.3	41.8	46.3	42.2	42.8	37.9
4th	19.6	20.3	15.8	23.2	22.6	25.6	19.6
5th	43.2	45.5	46.5	50.6	48.3	44.1	37.7
6th	21.8	27.9	23.1	31.2	40.8	30.6	29.6
7th	12.8	16.4	13.3	26.0	31.5	22.2	22.3
Average	29.9	32.9	28.1	35.5	37.1	33.1	29.4

*Pounds of N — P_2O_5 — K_2O per acre, respectively.

Where grazing is practiced, the grasses may also be benefited by phosphorus in the manure deposits.

Fertilizer Recovery

Percentage recovery of applied nitrogen (table 4) shows that within all fertilizer treatments, the five-year average recovery was greatest for crested wheatgrass followed in order by bromegrass and Russian wildrye. The treatment resulting in the greatest nitrogen recovery varied slightly for the three grasses. Maximum percentage nitrogen recovery by crested wheatgrass and bromegrass was reached with the 60-60-0 treatment, whereas, maximum recovery by Russian wildrye was obtained with the 60-60-60 treatment. It was noted that regardless of grass species maximum recovery was obtained when phosphorus accompanied nitrogen. The data indicate that the presence of phosphorus resulted in a more efficient use of fertilizer nitrogen by these grass species.

Progressive years of fertilization showed no effect on fertilizer recovery. The year in which recovery was greatest varied for fertilizer treatments and grass species, but the greatest recovery was obtained in either the first or fifth years of the study. These 2 years had growing season mean temperatures which were somewhat cooler. This suggests that in years of cool temperatures, when the release of soil nitrogen is low, grass may make more efficient use of fertilizer nitrogen. The low nitrogen recovery percentages obtained by these grasses show that they are very inefficient users of fertilizer nitrogen.

Phosphorus recovery by the three grasses, not shown, was very low, averaging 10.6 percent. Russian wildrye and bromegrass recovery percentage for phosphorus were approximately the same (8.2 percent), while the percentage for crested wheatgrass was somewhat higher (13.0 percent).

Summary

Annual applications of barnyard manure, nitrogen, nitrogen plus phosphorus and nitrogen plus phosphorus plus potassium were made for a seven-year period to plots of crested wheatgrass, Russian wildrye, and bromegrass. Herbage samples were collected and analyzed for nitrogen and phosphorus to determine protein and phosphorus content.

Yield increases from fertilizers for all grass species were largely attributed to nitrogen alone. Phosphorus in combination with nitrogen resulted in yields slightly greater than were obtained from the nitrogen alone treatments, but the differences were not significant. Fifteen tons of manure was approximately equal to 30 pounds of nitrogen for increasing yield.

The greatest increase in protein content of the grasses occurred when nitrogen fertilizer was applied alone. Phosphorus, in combination with nitrogen fertilizer, decreased the percentage protein in most instances below that of the nitrogen alone treatment. When 15 tons of manure were applied, the protein content of the grass was nearly equal to that which received 30 pounds of nitrogen.

The phosphorus content of the hay was generally reduced as the rate of nitrogen alone applications increased. Phosphorus, at the 30-pound rate, in combination with nitrogen, increased the phosphorus content of the hay to above the non-fertilized level except for crested wheatgrass. Sixty pounds of phosphorus gave small or no increase above the percentage obtained by the 30-pound application, but did increase the phosphorus content of crested wheatgrass to that of the non-fertilized level. Fifteen tons of manure increased the phosphorus content of the hay of all three species more than any other treatment.

The greatest percentage recovery of applied nitrogen was made by crested wheatgrass. Successive years of fertilization had no effect on the percentage recovery of the applied nitrogen, but in years of cooler temperature, recovery was increased.

LITERATURE CITED

ANDERSON, K. L., RALPH E. KRENZIN, AND J. C. HIDE. 1946. The effect of nitrogen fertilizer on bromegrass in Kansas. Jour. Amer. Soc. of Agron. 38:1058-1067.

KILCHER, MARK R. 1958. Fertilizer effects on hay production of three cultivated grasses in S. Saskatchewan. Jour. of Range Mangt. 11:231-234.

SNEVA, FOREST A., DONALD N. HYDER, AND C. S. COOPER. 1958. The influence of ammonium nitrate on the growth and yield of crested wheatgrass on the Oregon High Desert. Agron. Jour. 50:40-44.

STITT, R. E. 1958. Factors affecting yield and quality of dryland grasses. Agron. Jour. 50:136-138.

STITT, R. E., J. C. HIDE, AND ELMER FRAHM. 1955. Response of crested wheatgrass and volunteer sweetclover to nitrogen and phosphorus. Agron. Jour. 47:568-572.

WHITMAN, WARREN C., THOMAS J. CONLON, AND RAYMOND J. DOUGLAS. 1957. Response of old crested wheatgrass stands to nitrogen in Western North Dakota. No. Dak. Agr. Exp. Sta. Bimo. Bul. 19:141-148.