

Cost of Herbage Weight for Nitrogen Fertilization Treatments on Native Rangeland

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All of the nitrogen fertilization of native rangeland treatments increased total aboveground herbage weight to some degree. The nitrogen treatments increased herbage weight of mid cool season grasses and decreased herbage weight of warm season grasses. Native rangeland response to nitrogen fertilization was differentially affected by the quantity and source of nitrogen applied, and the vegetative communities on different range sites were affected by variation in soil characteristics, soil water content, plant species composition, and health status of the ecosystem. The fertilization treatments with the greatest production of total herbage weight may not be the treatments that are the most effective or lowest cost. This report evaluates the nitrogen fertilization treatments from five native rangeland plot studies for treatment effectiveness and herbage costs.

Procedure

Five nitrogen fertilization of native rangeland plot studies were conducted at the Dickinson Research Extension Center between 1957 and 1987. Plot study I (1957) was conducted on a heavily grazed site with an unfertilized control and ammonium nitrate treatments of 50 lbs N/ac, 100 lbs N/ac, and 150 lbs N/ac applied annually. Plot study II (1962-1963) was conducted on a creek terrace site and an upland slope site with an unfertilized control and ammonium nitrate treatments of 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac applied annually. Plot study III (1964-1969) was conducted on a Havre overflow, Manning silty, Vebar sandy, and Rhoades thin claypan range sites with an unfertilized control and ammonium nitrate treatments of 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac applied annually. Plot study IV (1970-1978) was conducted on an upland range site with an unfertilized control and ammonium nitrate treatments of 67 lbs N/ac and 100 lbs N/ac applied annually, 67 lbs N/ac and 100 lbs N/ac applied biennially, and 200 lbs N/ac, 300 lbs N/ac, and 400 lbs N/ac applied one time. Plot study V (1982-1987) was conducted on a Moreau clayey range site with an unfertilized control and ammonium nitrate and urea treatments of 40 lbs N/ac and 60 lbs N/ac applied annually, and 40 lbs N/ac, 60 lbs N/ac, and 100 lbs N/ac applied biennially.

Nitrogen fertilizer costs were the actual costs paid during plot study V with ammonium nitrate at \$0.24 per pound of nitrogen, and urea at \$0.25 per pound of nitrogen. Land rent value for grazinglands in North Dakota taken from the North Dakota Agricultural Statistics Service, 1998, was the mean rent in fifteen western counties at \$8.76 per acre.

Herbage cost was compared and evaluated from the cost of herbage weight per ton. Herbage cost per ton on the unfertilized treatments was determined first, by dividing the grazingland rent cost per acre by the mean total herbage weight produced on the unfertilized treatment to derive cost per pound of herbage; then, cost per pound was multiplied by 2000 pounds to derive cost per ton of unfertilized herbage. Herbage cost per ton on the fertilized treatments was determined in three stages: first, the nitrogen cost per acre was determined by multiplying the nitrogen cost per pound by the quantity of nitrogen applied annually (or half the biennial rate); next, the nitrogen cost per acre was divided by the weight difference in mean total herbage weight produced on the fertilization treatments from the mean total herbage weight produced on the unfertilized treatments to derive cost per pound of herbage; then, cost per pound was multiplied by 2000 pounds to derive cost per ton for the additional herbage produced by the nitrogen treatments.

Treatment effectiveness was compared and evaluated from the herbage weight produced per pound of nitrogen applied. Pounds of herbage per pound of nitrogen was determined by dividing the quantity of nitrogen applied annually (or half the biennial rate) by the weight difference in mean total herbage weight produced on the fertilization treatments from the mean total herbage weight produced on the unfertilized treatments.

Results and Discussion

The mean total herbage weight produced on the fertilization treatments was 594.80 pounds greater than the mean total herbage weight produced on the unfertilized treatments. The weight difference in mean total herbage weight produced on the fertilization treatments was 300.3 lbs, 819.0 lbs, and 876.0 lbs greater for ammonium nitrate annually

applied at treatment rates of 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac, respectively, and this increase in herbage weight on the fertilization treatments was 21.6%, 52.9%, and 57.5% greater, respectively, than the total herbage weight produced on the unfertilized treatments. Ammonium nitrate treatments applied biennially produced about 54.3% of the total herbage weight produced on the annually applied treatments. Ammonium nitrate treatments produced a mean 5.4% greater total herbage weight than produced on the urea treatments (tables 1-6).

Cost of unfertilized herbage weight per ton on plot study I, plot study II, III, and IV, and plot study V was \$9.84, \$11.59, and \$12.75 per ton of herbage, respectively. The mean cost of herbage weight on the fertilization treatments was \$51.39 per ton. Cost of fertilized herbage weight on most of the plot study sites and fertilization treatment rates ranged between \$32.00 and \$84.00 per ton, with the lowest cost at \$24.19 per ton, and the highest cost at \$112.21 per ton. The mean cost of herbage weight on the ammonium nitrate annually applied treatment rates of 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac was \$62.34, \$41.58, and \$60.40 per ton, respectively. The cost of herbage weight on the ammonium nitrate treatments applied biennially were in the same range of costs per ton as the costs of herbage weight on the annually applied treatments. The cost of herbage weight on the urea treatments was about \$13.23 per ton greater than the cost of herbage weight on the ammonium nitrate treatments (tables 7-8).

The mean percent increase in cost of fertilized herbage weight was 373.56% greater than the cost of herbage weight on the unfertilized treatments. The percent increase in the cost of fertilized herbage weight for most of the fertilization treatments ranged between 160% and 600% greater than the cost of unfertilized herbage weight. More than 80% of the fertilization treatments had herbage weight costs that were greater than 200% of the unfertilized herbage cost. None of the fertilization treatments had herbage weight costs that were less than 120% greater than the herbage weight costs on the unfertilized treatments. The mean percent increase in cost of fertilized herbage weight on the ammonium nitrate annually applied treatment rates of 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac was 502.01%, 279.06%, and 471.28% greater, respectively, than the cost of unfertilized herbage weight. The biennially applied ammonium nitrate treatments had an increase of 184.76% on the 67 lbs N/ac rate and had a reduction of 138.41% on the 100 lbs N/ac rate in cost of herbage weight from the cost of herbage weight on the respective annually applied treatments. The percent increase in the cost of

herbage weight on the urea treatments was 104.18% greater than the percent increase in the cost of herbage weight on the ammonium nitrate treatments (tables 9-10).

On native rangeland grazinglands, about 50% of the produced herbage is required by the plants to remain healthy and productive and about 50% of the produced herbage is not needed by the plants and is expendable. About 50% of the plant expendable herbage is lost from the plant by leaf senescence and by grazing of insects and wildlife. The other 50% of the plant expendable herbage is ingested as forage by grazing livestock. About 25% of the produced herbage weight is captured through grazing by livestock as forage. The cost of forage weight is four times greater than the cost of herbage weight. Fertilization treatments with herbage weight costs of \$32.00 and \$84.00 per ton would have forage weight costs of \$128.00 and \$336.00 per ton, respectively.

Cost of herbage weight per ton on all of the annual and biennial ammonium nitrate and urea fertilization treatments were too great to be cost effective. More than 62% of the fertilization treatments had herbage weight costs greater than \$40 per ton, or forage weight costs greater than \$160 per ton. Only one fertilization treatment had herbage weight costs less than \$30 per ton or forage weight costs of less than \$120 per ton.

Unfertilized treatments with herbage weight costs of \$11.59 per ton would have forage weight costs of \$46.36 per ton. Cost of herbage weight per ton on unfertilized treatments were not excessive and could be cost effective.

The primary reason for the high herbage weight costs on the fertilization treatments was low pounds of herbage produced per pound of nitrogen applied. The mean weight of herbage produced per pound of nitrogen applied was 10.55 pounds of herbage. The herbage weight produced per pound of nitrogen on most of the fertilization treatments ranged between 8.0 and 14.6 pounds of herbage, with the lowest at 4.3 pounds of herbage and the greatest at 17.0 pounds of herbage. The mean pounds of herbage per pound of nitrogen on the ammonium nitrate annually applied treatment rates of 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac was 9.1 lbs, 12.2 lbs, and 8.8 lbs of herbage. The pounds of herbage per pound of nitrogen on the ammonium nitrate treatments applied biennially were in the same range of pounds of herbage per pound of nitrogen as on the annually applied treatments. The ammonium nitrate treatments produced 2.43 pounds of herbage per

pound nitrogen greater than that produced on the urea treatments (tables 11-12).

With few pounds of herbage produced per pound of nitrogen, each pound of herbage had a high cost and each ton of herbage produced on the fertilization treatments cost substantially more than the cost of herbage produced on the unfertilized treatments. Based on the cost of the additional herbage weight produced on the fertilization treatments, the practice of nitrogen fertilization of native rangeland will not be profitable.

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Table 1. Mean nitrogen costs and herbage costs of fertilization treatments on a heavily grazed site, plot study I, 1957.

Treatments	Total Yield	Weight Difference from Unfertilized	Percent Difference from Unfertilized	Herbage Weight per Pound of Nitrogen	Nitrogen Cost @\$0.24/lb	Herbage Cost
	lbs/ac	lbs/ac	%	lbs	\$/ac	\$/ton
Unfertilized	1781.00					9.84
50 lbs N	2456.00	675.00	37.90	13.50	12.00	35.56
100 lbs N	3765.00	1984.00	111.40	19.84	24.00	24.19
150 lbs N	3220.00	1439.00	80.80	9.59	36.00	50.03

Table 2. Mean nitrogen costs and herbage costs of fertilization treatments on two range sites, plot study II, 1962-1963.

Treatments	Total Yield	Weight Difference from Unfertilized	Percent Difference from Unfertilized	Herbage Weight per Pound of Nitrogen	Nitrogen Cost @\$0.24/lb	Herbage Cost
	lbs/ac	lbs/ac	%	lbs	\$/ac	\$/ton
Creek terrace site						
Unfertilized	1521.00					11.52
33 lbs N	1932.50	411.50	27.05	12.47	7.92	38.49
67 lbs N	2440.00	919.00	60.42	13.72	16.08	34.99
100 lbs N	2431.50	910.50	59.86	9.11	24.00	52.72
Upland slope site						
Unfertilized	1358.00					12.90
33 lbs N	1825.00	467.00	34.39	14.15	7.92	33.92
67 lbs N	2233.00	875.00	64.43	13.06	16.08	36.75
100 lbs N	2260.00	902.00	66.42	9.02	24.00	53.22
Mean of two sites						
Unfertilized	1439.50					12.17
33 lbs N	1878.75	439.25	30.51	13.31	7.92	36.06
67 lbs N	2336.50	897.00	62.31	13.39	16.08	35.85
100 lbs N	2345.75	906.25	62.96	9.06	24.00	52.97

Table 3. Mean nitrogen costs and herbage costs of fertilization treatments on four range sites, plot study III, 1964-1969.

Treatments	Total Yield	Weight Difference from Unfertilized	Percent Difference from Unfertilized	Herbage Weight per Pound of Nitrogen	Nitrogen Cost @\$0.24/lb	Herbage Cost
	lbs/ac	lbs/ac	%	lbs	\$/ac	\$/ton
Havre overflow range site						
Unfertilized	2514.33					6.97
33 lbs N	2655.50	141.17	5.61	4.28	7.92	112.21
67 lbs N	3368.00	853.67	33.95	12.74	16.08	37.67
100 lbs N	3079.17	564.84	22.46	5.65	24.00	84.98
Manning silty range site						
Unfertilized	1533.50					11.42
33 lbs N	1743.17	209.67	13.67	6.35	7.92	75.55
67 lbs N	2477.33	943.83	61.55	14.09	16.08	34.07
100 lbs N	2909.33	1375.83	89.72	13.76	24.00	34.89
Vebar sandy range site						
Unfertilized	1331.67					13.16
33 lbs N	1665.83	334.16	25.09	10.13	7.92	47.40
67 lbs N	2287.00	955.33	71.74	14.26	16.08	33.66
100 lbs N	2331.00	999.33	75.04	9.99	24.00	48.03
Rhoades thin claypan range site						
Unfertilized	1011.20					17.33
33 lbs N	1249.60	238.40	23.58	7.22	7.92	66.44
67 lbs N	1474.00	462.80	45.77	6.91	16.08	69.49
100 lbs N	1524.20	513.00	50.73	5.13	24.00	93.57
Mean of four range sites						
Unfertilized	1597.68					10.97
33 lbs N	1828.53	230.85	14.45	7.00	7.92	68.62
67 lbs N	2401.58	803.90	50.32	12.00	16.08	40.00
100 lbs N	2460.93	863.25	54.03	8.63	24.00	55.60

Table 4. Mean nitrogen costs and herbage costs of fertilization treatments on the upland range site, plot study IV, 1970-1978.

Treatments	Total Yield	Weight Difference from Unfertilized	Percent Difference from Unfertilized	Herbage Weight per Pound of Nitrogen lbs	Nitrogen Cost @\$0.24/lb	Herbage Cost
	lbs/ac	lbs/ac	%		\$/ac	\$/ton
Unfertilized	2252.56					7.81
67 lbs N EOY	2525.63	273.07	12.12	8.15	8.04	58.89
67 lbs N EY	2975.89	723.33	32.11	10.80	16.08	44.46
100 lbs N EOY	2868.00	615.44	27.32	10.77	13.71	44.57
100 lbs N EY	3119.34	866.78	38.48	8.67	24.00	55.38
200 lbs N OT	2426.56	174.00	7.72	7.83	5.33	61.26
300 lbs N OT	2865.67	613.11	27.22	18.40	8.00	26.10
400 lbs N OT	2818.33	565.77	25.12	12.73	10.67	37.72

Table 5. Mean nitrogen costs and herbage costs of ammonium nitrate fertilization treatments on the Moreau clayey range site, plot study V, 1982-1985.

Treatments	Total Yield	Weight Difference from Unfertilized	Percent Difference from Unfertilized	Herbage Weight per Pound of Nitrogen lbs	Nitrogen Cost @\$0.24/lb	Herbage Cost
	lbs/ac	lbs/ac	%		\$/ac	\$/ton
Unfertilized	1374.61					12.75
Ammonium nitrate						
40 lbs N EOY	1666.11	291.50	21.21	14.58	4.80	32.93
40 lbs N EY	1865.74	491.13	35.73	12.28	9.60	39.09
60 lbs N EOY	1885.04	510.43	37.13	17.01	7.20	28.21
60 lbs N EY	1943.65	569.04	41.40	9.48	14.40	50.61
100 lbs N EOY	1936.70	562.09	40.89	11.24	12.00	42.70

Table 6. Mean nitrogen costs and herbage costs of urea fertilization treatments on the Moreau clayey range site, plot study V, 1982-1985.

Treatments	Total Yield	Weight Difference from Unfertilized	Percent Difference from Unfertilized	Herbage Weight per Pound of Nitrogen lbs	Nitrogen Cost @\$0.25/lb	Herbage Cost
	lbs/ac	lbs/ac	%		\$/ac	\$/ton
Unfertilized	1374.61					12.75
Urea						
40 lbs N EOY	1561.66	187.05	13.61	9.35	5.00	53.46
40 lbs N EY	1791.33	416.72	30.32	10.42	10.00	47.99
60 lbs N EOY	1741.81	367.20	26.71	12.24	7.50	40.85
60 lbs N EY	1737.45	362.84	26.40	6.05	15.00	82.68
100 lbs N EOY	2094.64	720.03	52.38	14.40	12.50	34.72

Table 7. Cost of herbage weight per ton on annual and biennial ammonium nitrate fertilization treatments and on unfertilized treatments.

Study Sites	Treatment Rates			
	0 lbs N/ac \$/ton	33 lbs N/ac \$/ton	67 lbs N/ac \$/ton	100 lbs N/ac \$/ton
Annual Treatments				
Creek terrace site	11.52	38.49	34.99	52.72
Upland slope site	12.90	33.92	36.75	53.22
Havre overflow range site	6.97	112.21	37.67	84.98
Manning silty range site	11.42	75.55	34.07	34.89
Vebar sandy range site	13.16	47.40	33.66	48.03
Rhoades thin claypan range site	17.33	66.44	69.49	93.57
Upland range site	7.81	-	44.46	55.38
Mean	11.59	62.34	41.58	60.40
Biennial Treatments				
Upland range site	7.81	-	58.89	44.57

Table 8. Cost of herbage weight per ton on annual and biennial ammonium nitrate and urea fertilization treatments and on the unfertilized treatment.

Study Sites	Treatment Rates			
	0 lbs N/ac \$/ton	40 lbs N/ac \$/ton	60 lbs N/ac \$/ton	100 lbs N/ac \$/ton
Moreau clayey range site				
Annual Treatments				
Ammonium nitrate	12.75	39.09	50.61	-
Urea	12.75	47.99	82.68	-
Biennial Treatments				
Ammonium nitrate	12.75	32.93	28.21	42.70
Urea	12.75	53.46	40.85	34.72

Table 9. Percent increase in cost of herbage weight per ton on annual and biennial ammonium nitrate fertilization treatments and cost of herbage weight per ton on unfertilized treatments.

Study Sites	Treatment Rates			
	0 lbs N/ac \$/ton	33 lbs N/ac %	67 lbs N/ac %	100 lbs N/ac %
Annual Treatments				
Creek terrace site	11.52	234.11	203.73	357.64
Upland slope site	12.90	162.95	184.88	312.56
Havre overflow range site	6.97	1509.90	440.46	1119.23
Manning silty range site	11.42	561.56	198.34	205.52
Vebar sandy range site	13.16	260.18	155.78	264.97
Rhoades thin claypan range site	17.33	283.38	300.98	439.93
Upland range site	7.81	-	469.27	609.09
Mean	11.59	502.01	279.06	471.28
Biennial Treatments				
Upland range site	7.81	-	654.03	470.68

Table 10. Percent increase in cost of herbage weight per ton on annual and biennial ammonium nitrate and urea fertilization treatments and cost of herbage weight per ton on the unfertilized treatment.

Study Sites	Treatment Rates			
	0 lbs N/ac \$/ton	40 lbs N/ac %	60 lbs N/ac %	100 lbs N/ac %
Moreau clayey range site				
Annual Treatments				
Ammonium nitrate	12.75	206.59	296.94	-
Urea	12.75	276.39	548.47	-
Biennial Treatments				
Ammonium nitrate	12.75	158.27	121.25	234.90
Urea	12.75	319.29	220.39	172.31

Table 11. Herbage weight (in pounds per acre) per pound of nitrogen fertilizer applied and herbage weight on unfertilized treatments.

Study Sites	Treatment Rates			
	0 lbs N/ac lbs/ac	33 lbs N/ac lbs/ac/lb N	67 lbs N/ac lbs/ac/lb N	100 lbs N/ac lbs/ac/lb N
Annual Treatments				
Creek terrace site	1521.00	12.47	13.72	9.11
Upland slope site	1358.00	14.15	13.06	9.02
Havre overflow range site	2514.33	4.28	12.74	5.65
Manning silty range site	1533.50	6.35	14.09	13.76
Vebar sandy range site	1331.67	10.13	14.26	9.99
Rhoades thin claypan range site	1011.20	7.22	6.91	5.13
Upland range site	2252.56	-	10.80	8.67
Mean	1646.04	9.10	12.23	8.76
Biennial Treatments				
Upland range site	2252.56	-	8.15	10.77

Table 12. Herbage weight (in pounds per acre) per pound of nitrogen fertilizer applied and herbage weight on the unfertilized treatment.

Study Sites	Treatment Rates			
	0 lbs N/ac lbs/ac	40 lbs N/ac lbs/ac/lb N	60 lbs N/ac lbs/ac/lb N	100 lbs N/ac lbs/ac/lb N
Moreau clayey range site				
Annual Treatments				
Ammonium nitrate	1374.61	12.28	9.48	-
Urea	1374.61	10.42	6.05	-
Biennial Treatments				
Ammonium nitrate	1374.61	14.58	17.01	11.24
Urea	1374.61	9.35	12.24	14.40