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Fertilization and Improvement of Native Subirrigated Meadows in Nebraska

P. Ehlers

G. Viehmeyer

R. Ramig

E. M. Brouse

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PAUL EHLERS, GLENN VIEHMEYER, ROBERT RAMIG, AND E. M. BROUSE

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THE EXPERIMENT STATION, UNIVERSITY OF NEBRASKA
COLLEGE OF AGRICULTURE, LINCOLN
W. V. LAMBERT, DIRECTOR
M. L. BAKER, ASSOCIATE DIRECTOR

Recommendations for fertilizing meadows with a water table between 6 and 30 inches.

1. Because of the wide variation in the response of subirrigated meadows to the application of commercial fertilizers, it is suggested that small strip treatments be tried before making an extensive application.

2. Applying nitrogen fertilizer singly is not recommended as a general practice.

3. Phosphorus fertilizer applied singly is recommended for those meadows where legumes are to be established and for meadows with medium to heavy stands of legumes.

4. Potassium fertilizer is not recommended at this time.

5. For maximum yields both nitrogen and phosphorus fertilizers should be applied. Suggested rates are 30 to 60 pounds of nitrogen per acre plus 40 pounds of available phosphorus (P_2O_5) per acre.

6. Apply phosphorus fertilizer in either the fall or early spring.

7. Phosphorus fertilizer should not be applied to meadows infested with sweetclover unless management practices are modified to control or utilize this legume.

8. For meadows where cool-season grasses predominate, nitrogen fertilizer should be applied in early spring (March-April). Where warm-season grasses predominate, the application should be made in late spring (late May or early June).

Fertilization and Improvement of Native Subirrigated Meadows in Nebraska[1]

PAUL EHLERS, GLENN VIEHMEYER, ROBERT RAMIG, AND E. M. BROUSE[2]

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THE NEBRASKA SANDHILLS, a beef factory without equal in the nation, occupies an area of approximately thirteen million acres. These lands are the backbone of Nebraska's multimillion dollar cattle industry. Despite their importance to the economy of the state and of the nation, only limited studies concerning the management and improvement of these grasslands have been conducted.

It is the purpose of this circular to summarize the 1948-51 results of fertilizer applications upon subirrigated native meadows. These lands occupy but a small portion of the total acreage (2 to 3 per cent) of the sandhill area, being greatly exceeded in area by the higher grazing and hay lands. In spite of their limited area, the wet meadows have a profound effect upon the economy of the individual ranch unit and of the region. It is upon these lands that the cattleman depends to a large extent for winter feed. The efficiency of the ranch unit is determined by the ratio of summer grazing to winter forage. These lands were selected for study because of their importance in the production of winter forage.

DESCRIPTION OF SITES

The soils of the experimental meadows were of two general types: (1) sandy soils of the wet valleys of the sandhills and (2) finer textured soils of the Platte and Loup Valleys. Fifteen of the sites were of the first type, ranging in texture from fine sands to very fine sandy loams. The topsoils were dark colored, ranging from a few inches to 2 or

[1] These studies were conducted by the Valentine Substation, North Platte Substation and the Outstate Testing Project of the Nebraska Agricultural Experiment Station. Acknowledgment is made to ranchers, county extension agents and others who assisted with the experimental work.

[2] Assistant in Agronomy, Outstate Testing; Assistant in Horticulture, North Platte Substation; Assistant in Agronomy, North Platte Substation; and Superintendent, Valentine Substation, respectively.

more feet in depth above sandy material extremely low in organic matter. Buried dark-colored soils above light-colored sand frequently occurred at depths of 30 or more inches.

Three sites of the second type were on clay loam and silt loam soils in the Platte and South Loup River Valleys. These soils were darker colored and deeper than the sandy soils previously described. Gravel strata occurred at depths of 4 feet or more in the Platte Valley sites but were not encountered in the other river valley locations.

The vegetation of subirrigated meadows is made up of plant communities that vary with the depth to the water table. Such communities are zonal. These zones may be clearly defined when changes in

TABLE 1.—Principal species in the plant communities of native meadows in relation to the depth of water table.

Vegetation zone	Depth to water table, in.	Native plants[1]	Introduced plants	
			Grasses	Legumes
I	0	Aquatic plants		
II	1 to 18	Sedges Sloughgrass *(Spartina pectinata)* Northern reedgrass *(Calamagrostis canadensis)*	Bluegrass *(Poa pratensis)* Redtop *(Agrostis alba)* Reed canarygrass *(Phalaris arundinacea)*	Alsike clover *(Trifolium hybridum)* White clover *(Trifolium repens)*
III	18 to 30	Sedges Big bluestem *(Andropogon furcatus)* Indiangrass *(Sorgastrum nutans)* Switchgrass *(Panicum virgatum)*	Bluegrass *(Poa pratensis)* Redtop *(Agrostis alba)* Timothy *(Phleum pratense)*	Red clover *(Trifolium pratense)* Black medic *(Medicago lupulina)* Sweetclover *(Melilotus alba)*
IV	30 to 60	Big bluestem *(Andropogon furcatus)* Little bluestem *(Andropogon scoparius)* Indiangrass *(Sorgastrum nutans)* Switchgrass *(Panicum virgatum)*	Bluegrass *(Poa pratensis)*	Black medic *(Medicago lupulina)* Sweetclover *(Melilotus alba)*
V	over 60	Little bluestem *(Andropogon scoparius)* Hairy grama grass *(Bouteloua hirsuta)* Blue grama grass *(Bouteloua gracilis)* Needlegrass *(Stipa comata)* Sand reedgrass *(Calamovilfa longifolia)*		

[1] No native legume of importance as a forage plant occurs.

TABLE 2.—Location, vegetation zone, legume stand, and soil reaction of the experimental meadows.

Site number	County	Cooperator	Address	Vegetation zone[1]	Legume stand	pH Top-soil	pH Sub-soil
			1948				
1	Thomas	Harold Robinson	Thedford	II-III	light-medium	....	....
2	Thomas	T. L. McCully	Thedford	II-III	light-medium	....	....
			1949				
3	Lincoln	Carl Schwartzlander	North Platte	III	light	8.2	8.5
4	Logan	Mildale Ranch	Gandy	II-III	none	....	....
			1950				
5[2]	Lincoln	Carl Schwartzlander	North Platte	III	medium-heavy	8.2	8.5
6	Logan	Marvin Perry	Stapleton	III	light-medium	8.2	8.0
7	Lincoln	Hansen Ranch	North Platte	III	medium-heavy	8.1	8.2
			1951				
8	Lincoln	Hansen Ranch	North Platte	II-III	none[3]	7.9	8.2
9	Logan	Ed Salisbury	Stapleton	II-III	none[4]	8.2	7.6
10	Morrill	Rush Creek Land and Cattle Co.	Angora	III	none	8.1	8.1
11	Grant	Lloyd Snyder	Hyannis	II-III	none	7.7	7.5
12	Grant	Earl Monahan	Hyannis	II-III	light	8.0	8.0
13	Thomas	Harold Robinson	Thedford	II-III	light-medium	7.6	7.1
14	Blaine	Garrett Roseberry	Dunning	II-III	light	6.5	6.7
15	Blaine	Kyle Cox	Purdum	II	none	6.2	5.7
16	Brown	Salzman & Son	Ainsworth	II-III	medium-heavy	7.1	7.1
17	Cherry	P. H. Young	Valentine	II-III	light-medium	7.5	8.0
18	Cherry	Ted McGinley	Valentine	II-III	light-medium	6.0	5.8

[1] See Table 1 for species zonation.
[2] Same site as 3 in 1949.
[3] Sprayed with 2,4-D in the fall of 1950 and a new seeding of a legume mixture was made in the spring of 1951.
[4] Mixture of legumes seeded in the spring.

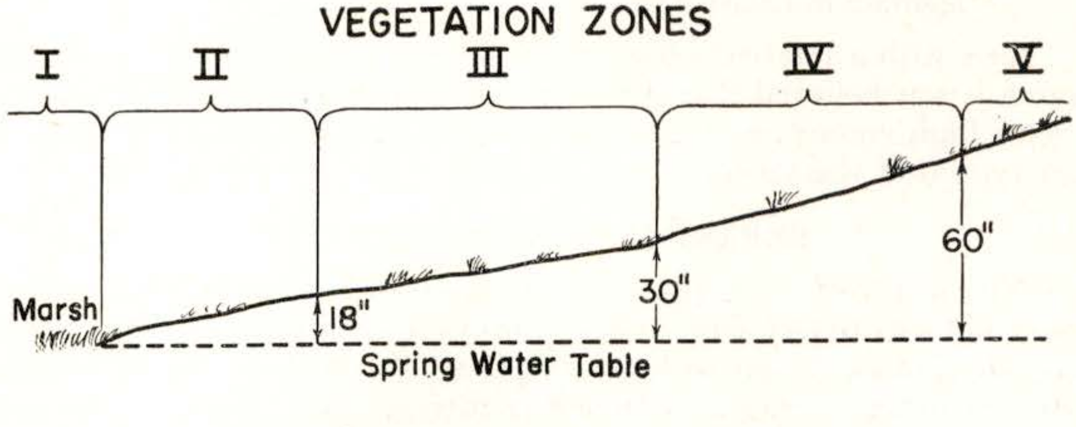

FIG. 1.—Vegetation zones in relation to the depth to the water table.

water table are abrupt, or may merge into each other where there is a gradual change in the depth to the water table. The zonal pattern of plant communities is illustrated in Figure 1 and described in Table 1. The location, vegetation zone, legume stand, and soil reaction of the meadows studied are shown in Table 2.

In many of the subirrigated meadows introduced grasses and legumes occupy much of the area, often to the detriment of the native species. These plants have entered either as chance invaders or as a result of seeding.

In a number of meadows Kentucky bluegrass and sweetclover present a problem in management because of their early maturity. Redtop was dominant in some sites where it had been seeded, and the more desirable native bluestems, Indiangrass and switchgrass, remained only as relicts of the original vegetation. In certain meadows alsike and red clovers have been established as important components of the plant community. In other meadows black medic, often called hop clover, was present, probably the result of seeding as an impurity in grass and clover seed. Alsike clover, red clover, and hop clover are desirable forage plants that improve the quality of hay produced. Their presence indicates the possibility of meadow improvement by seeding legumes.

The present studies were undertaken to determine the possibility of increasing hay yield and forage quality by applying commercial fertilizer to native subirrigated meadows. Questions which prompted the study were:

(1) Will commercial fertilizers increase hay yields?

(2) If so, what fertilizer practice will give the most returns?

(3) Will commercial fertilizers affect hay quality?

(4) Where will applications of commercial fertilizer be profitable?

(5) Will legumes supply a part or all of the nitrogen needed for optimum yields?

(6) What are the best methods of establishing and perpetuating legumes in native meadows?

Sites with a relatively high water table were selected for study because it was believed that they were potentially capable of producing yields high enough to justify the expense of fertilization. Such sites are typical of vegetation zones II and III as described in Table 1.

EXPERIMENTAL PROCEDURE

The fertilizers were applied as a top-dressing to plots 60 to 80 feet long and 6 to 10 feet wide. These plots were arranged in a randomized complete block design with four replications. Nitrogen fertilizer was applied in the spring as ammonium nitrate (33.5 per cent nitrogen) while phosphorus fertilizer was applied as superphosphate (20 and 43 per cent available P_2O_5) in the fall in some cases and early in the spring in others. Potassium fertilizer was applied in the spring as potassium chloride (60 per cent available K_2O). Nitrogen, phosphorus, and potassium fertilizers were applied singly and in combination. In the tables the amounts of nitrogen, available phosphorus, and available potassium are expressed as pounds of N, P_2O_5, and K_2O, respectively. Samples for yield determinations were obtained by mowing a single swath 20 to 40 feet long and 34 inches wide from the center of each plot. The green forage weights from each swath were recorded and a small sample was taken for moisture, protein, and phosphorus determinations. All hay yields were calculated on an air-dry basis.

If the difference in yield between treatments is as great as or greater than the least significant difference shown in the tables, it is assumed that the differences is due to fertilizer treatment.

RESULTS OF FERTILIZER APPLICATION

Nitrogen. Nitrogen fertilizer applied singly caused increased hay yields ranging from 127 to 3004 pounds per acre, the increases being significant in 9 of the 18 experiments (Table 3). Nitrogen response was indicated by a darker green color and more vigorous growth of the grasses. In mixed meadows containing grasses and legumes, nitrogen fertilizer increased the yield of grasses but had little or no effect on the yield of legumes (Table 4). In all experiments nitrogen fertilizer applied alone failed to give maximum yield increases of hay. There was no significant residual effect of the nitrogen fertilizer even at the 120-pound rate on the one location where residual effects were studied (Table 5).

Phosphorus. According to soil tests the soils were low to very low in soluble phosphorus at all sites. Response of the meadows to phosphorus fertilizer applied singly ranged from slight decreases to substantial increases in yield of hay. Significant increases in yield were obtained in 9 of the 18 experiments (Table 3). Plots receiving phosphorus fertilizer could be identified by the lighter green color of the grasses early in the season and by the increase in number and size of the legume plants present. Hay yields were not increased by the application of phosphorus fertilizer alone unless legumes were present (Tables 2, 3, and 4).

From observations made on all sites where legumes were present and from data given in Tables 4 and 6, it appears that phosphorus fertilizer aids in the establishment of legume seedlings. Because of this aid in establishing legume seedlings and the stimulation of legume growth, the effect of phosphorus fertilizer may be evident for two or more years (Table 5). Phosphorus fertilizers also increased the phosphorus content of the hay crop (Table 8).

TABLE 3.—Influence of nitrogen, phosphorus, and potassium fertilizers applied singly on the yield of hay from subirrigated meadows.

Location, site number[1]	Yield of nonfertilized plot, lbs/acre	Increase in yield of hay due to fertilizer, pounds per acre						Least significant difference (.05), lbs/acre
		Pounds N/acre			Pounds P_2O_5/acre		Pounds K_2O/acre	
		40	60	80	40	80	40	
				1948				
1	1880	440	....	440	520	1060	....	500
2	3080	360	....	980	700	760	....	900
				1949				
3	1440	....	1170	....	590	....	–40	460
4	2820	....	210	....	–350	....	–320	....
				1950				
5	1630	....	780	....	1800	....	–230	1190
6[2]	4280	....	750	....	1880	....	750	970
7	1100	....	590	....	940	....	–40	540
				1951				
8	3070	750[3]	1410	1940[4]	840	1060	....	770
9	2750	....	270	....	–270	....	–220	500
10	2580	....	1030	....	290	....	–360	670
11	1430	1680	....	3000	400	....	....	720
12	3460	460	630	....	....	–300	....	850
13	2200	210	....	990	1530	....	....	940
14	3480	1540	....	2040	670	....	....	1200
15	1940	200	....	370	–10	....	....	310
16	2330	1310	....	1210	1930	....	....	1500
17	3240	130	....	570	780	....	....	....
18	2780	500	....	920	1300	....	....	960

[1] See Tables 1 and 2 for meadow composition and location.
[2] Fertilizer applied in 1950 to the same plots and in the same amounts as at location 3 in 1949.
[3] Nitrogen applied at 30 pounds per acre.
[4] Nitrogen applied at 90 pounds per acre.

Nitrogen and phosphorus in combination. In general, a combination of nitrogen and phosphorus fertilizers was superior to applications of either nitrogen or phosphorus fertilizers alone (Tables 3 and 7). This combination produced the highest yields in all tests, with increases ranging from 32 to 254 per cent of nonfertilized plots. These increases were significant to highly significant in all except two of the experiments. Both legume and grass yields were increased by the combination of nitrogen and phosphorus fertilizers; however, the effect on legume yields was not as great as from an application of phosphorus fertilizer alone (Table 4).

Potassium. Potassium fertilizer applied singly had no significant effect on the yield of hay and decreased yields slightly in six of seven experiments (Table 3). Furthermore, potassium fertilizer in various combinations with nitrogen and phosphorus fertilizers had little effect upon yields except at two locations (Table 7).

Cost of increased hay production. The advisability of meadow fertilization is determined by the need for additional hay and the cost of producing such hay. Yield increases and production costs are inversely correlated. This is shown in Figures 2 and 3 where both costs and yields are presented for four types of meadows classified according to density of legume stands.

TABLE 4.—Influence of nitrogen and phosphorus fertilizers on the yields of grasses and legumes in mixed meadows.

Fertilizer applied, pounds per acre $N\text{-}P_2O_5$	Yield of hay, pounds per acre			Protein, per cent	
	Grasses	Legumes	Total	Grasses	Legumes
		Site 3, 1949			
0–0	1300	190	1490	6.7	13.8
60–0	2090	140	2240	7.8	14.1
0–40	1260	1240	2500	7.5	15.3
60–40	2660	530	3190	7.6	14.4
Least significant difference (.05)	1410	190	460	....	......
		Site 5, 1950			
0–0	1370	250	1630	7.0	......
60–0	2320	90	2410	8.5	......
0–40	1420	2010	3430	7.3	......
60–40	2740	290	3040	8.5	......
Least significant difference (.05)	790	950	1190	....	......
		Site 7, 1950			
0–0	860	240	1100	6.6	......
60–0	1380	310	1690	7.8	......
120–0	1190	260	1450	8.5	......
0–40	930	1120	2050	8.1	......
60–40	2610	1160	3760	7.3	......
120–40	2920	1100	4020	8.0	......
Least significant difference (.05)	420	430	540	....	......

TABLE 5.—Influence of nitrogen and phosphorus fertilizers applied in 1950 on hay yields in 1950 and 1951. Site 7, 1950, Site 8, 1951. Meadow contained grasses and legumes.

Fertilizer applied, pounds per acre $N\text{-}P_2O_5$	Yield of hay, pounds per acre		Increases due to fertilizer, pounds per acre	
	1950	1951	1950	1951
0–0	1100	3160	....	......
60–0	1690	3430	590	270
120–0	1450	3570	350	410
0–40	2050	4330	940	1170
60–40	3760	3750	2660	590
120–40	4020	3960	2920	810
Least significant difference (.05)	540	620	540	620

TABLE 6.—Influence of combinations of nitrogen, phosphorus, and potassium fertilizers on legume seedling establishment.[1]

Fertilizer applied, pounds per acre P_2O_5-K_2O	Number of legume seedlings per square foot at different rates of nitrogen fertilizer[2]			
	None	30 lbs. N/acre	60 lbs. N/acre	90 lbs. N/acre
		Site 8, 1951		
0–0	4.8	5.4	5.4	5.6
40–0	11.2	5.4	4.4	4.8
80–0	10.7	9.7	3.2	3.9
40–40	......	....	4.3	....
		Site 9, 1951		
0–0	8.8	....	7.1	....
40–0	9.5	9.5[3]	5.4	6.1[4]
0–40	9.4	....	6.1	....
40–40	13.9	....	4.7	....

[1] A legume mixture was seeded March 30 and 31, 1951.
[2] Counts made in the fall of 1951.
[3] 40 pounds N instead of 30 pounds N.
[4] 80 pounds N instead of 90 pounds N.

TABLE 7.—Influence of combinations of nitrogen, phosphorus, and potassium fertilizers on the yield of hay from wet meadows.

Location, site number[1]	Yield of non-fertilized plot, lbs/acre	Increase in hay yield, pounds per acre						Least significant difference (.05), lbs/acre
		40-40-0[2]	60-40-0	80-40-0	60-0-40	0-40-40	60-40-40	
				1948				
1	1880	780	....	1420	....	....	1360[3]	500
2	3080	1620	....	1600	....	....	920[3]	900
				1949				
3	1440	....	1430	....	810	370	1900	460
4	2820	....	110	....	70	–410	40	......
				1950				
5[4]	1630	....	1410	....	440	2390	3180	1190
6	4280	....	3230	....	930	2230	3470	970
7	1100	....	2660	....	460	700	2270	540
				1951				
8	3070	2110[5]	3010	2600[6]	....	....	2550	770
9	2750	670	1180	1600	420	280	830	500
10	2580	2770	2840	3370	1870	800	3340	670
11	1430	2270	....	3640	....	....	....	720
12	3460	890[7]	950[7]	1550[7]	....	....	....	850
13	2200	2610	....	2700	....	....	....	940
14	3480	1830	....	2970	....	....	....	1200
15	1940	480	....	620	....	....	....	310
16	2330	2590	....	3570	....	....	....	1500
17	3240	530	....	1030	....	....	....	......
18	2780	1660	....	2190	....	....	....	960

[1] See Tables 1 and 2 for meadow composition and location.
[2] Fertilizer applied in pounds per acre of N, P_2O_5 and K_2O, respectively.
[3] Nitrogen applied at 40 pounds of N per acre.
[4] Fertilizer applied 1950 to same plots and in same amounts as site 3 in 1949.
[5] Nitrogen applied at 30 pounds of N per acre.
[6] Nitrogen applied at 90 pounds of N per acre.
[7] Phosphorous applied at 80 pounds of P_2O_5 per acre.

TABLE 8.—Phosphorus content of hay from the fertilizer experiments conducted in 1950.

Fertilizer applied, pounds per acre $N\text{-}P_2O_5\text{-}K_2O$	Phosphorus content of hay, per cent			
	Site 5	Site 6	Site 7	Average
0–0–0	.08	.09	.08	.08
60–0–0	.08	.08	.08	.08
0–40–0	.12	.13	.10	.12
0–0–40	.09	.11	.08	.09
60–40–0	.10	.12	.10	.11
60–0–40	.09	.10	.10	.10
0–40–40	.15	.14	.12	.14
60–40–40	.14	.13	....	....
120–0–0	.08	.08	.09	.08
120–40–0	.13	.12	....	....

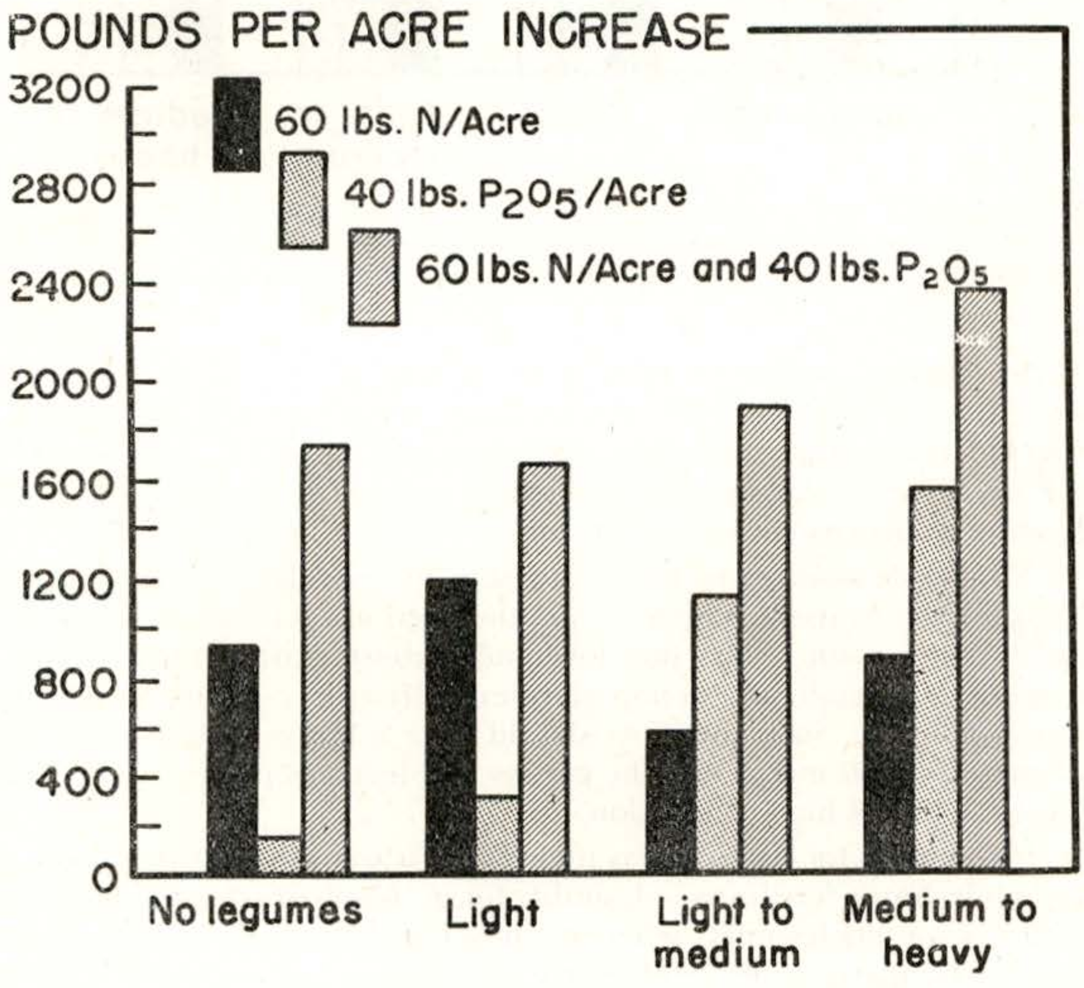

FIG. 2.—Increases in yield of hay from the application of commercial fertilizers to meadows containing different amounts of legumes. (In nine of the experiments the 60-pound rate of N was based on a mean of 40- and 80-pound rates.)

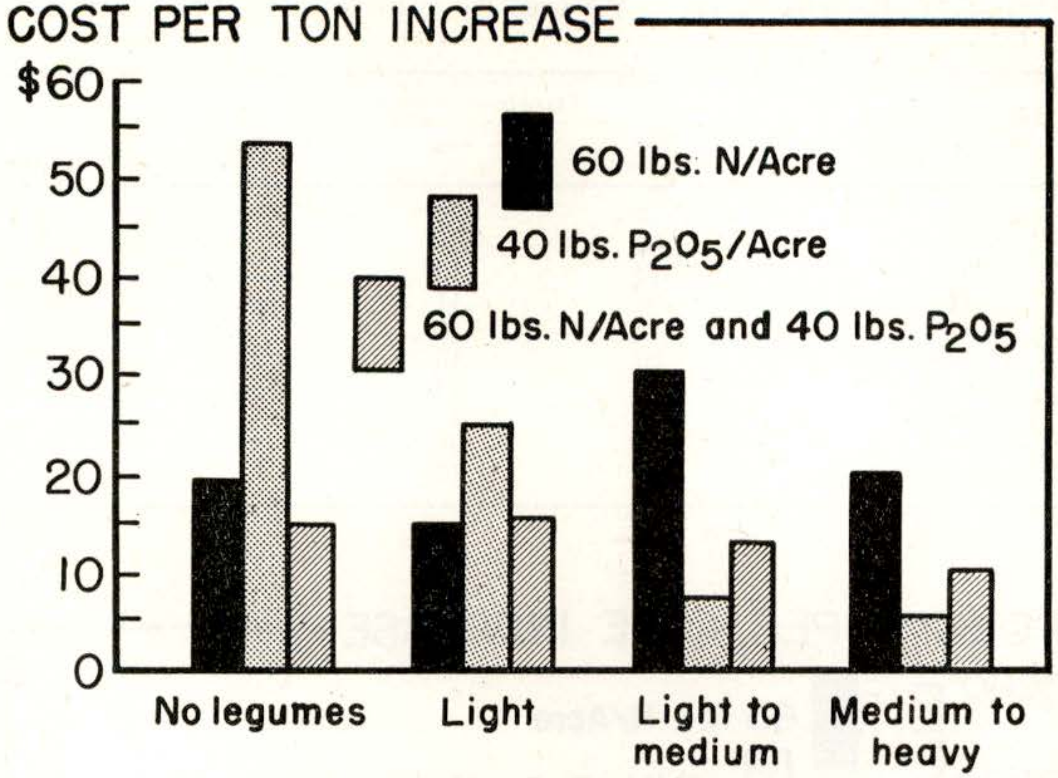

FIG. 3.—Cost per ton increase in yield of hay from the application of commercial fertilizers to meadows containing different amounts of legumes. (Assumed the following costs: N at 15 cents a pound and P_2O_5 at 10 cents a pound.)

In making any decision either for or against the use of fertilizer, the following things should be considered. First, how will the meadow respond to fertilizer and what treatment should be used? Second, is the need for additional hay immediate or can a slower program of meadow improvement be undertaken?

No simple answers to these questions are possible. Each meadow is a problem in itself. Furthermore, the need of each ranch unit must affect the decision. The meadow under consideration must have a potential for high production if rates of fertilizer discussed in this study are used. Such meadows should have a water table within the range of 6 to 30 inches and the grasses and legumes present should be those capable of high production.

If the need for more hay is immediate, a combination of nitrogen and phosphorus fertilizers is desirable for meadows or parts of meadows with few or no legumes; whereas phosphorus fertilizer will produce substantial increases in yield on meadows having a medium to heavy stand of legumes. In these experiments phosphorus fertilizer applied to meadows containing legumes gave the most economical increases in yield.

Cost of increased hay production ranged from $5.13 per ton of hay where legume stands were medium to heavy, to $7.15 where stands were light to medium, and up to $53.32 where there were no legumes (see Figure 3). Furthermore, increased amounts of legumes resulted in higher protein content of the hay.

Establishment of legumes. If the need for increased hay production is not immediate, a program of meadow improvement by introducing legumes may be undertaken. It is desirable to establish perennial legumes in native meadows to supply nitrogen for companion grasses and to improve hay quality. Most of the meadows where the water table ranges from 6 to 30 inches may be expected to support red and alsike clovers if phosphorus requirements of the legumes are supplied. Where the depth of the water table is greater than 30 inches, alfalfa and sweetclover are the only adapted legumes. It is difficult to obtain stands of these legumes except on the finer textured soils or under very favorable weather conditions.

To investigate the possibility of establishing legumes in meadows, a mixture of alsike, Ladino and red clovers, birdsfoot trefoil, and Ranger alfalfa was sown across the fertilizer plots of sites 8 and 9 in the spring of 1951. Alsike and red clovers were used because these species are established in many meadows of this region. Ladino clover was included as a possible third species adapted to meadows having a high water table; birdsfoot trefoil, to determine its range of adaptation in native meadows; and alfalfa for those sites with a water table deeper than 30 inches. Counts of established seedlings were made in October, at the end of the first growing season, and are presented in Table 6.

Counts taken at the end of the first growing season may be misleading for there may be a reduction of stand during the following winter. The stand counts in Table 6 indicate that nitrogen fertilizer applied singly had little effect on seedling establishment. When nitrogen fertilizer was applied in combination with phosphorus fertilizer, a reduction in seedling count occurred at the higher nitrogen levels. This is probably due to the increased competition of the grasses. The establishment and vigor of legume seedlings were improved on those plots receiving phosphorus fertilizer alone.

Effect upon the plant community. It is to be expected that changes in the species composition of the plant community may occur following the application of fertilizer to grasslands. It is probable that such changes will vary with the time and rate of application and the kind of fertilizer. In some cases the change will be beneficial; in others, detrimental. Certain trends which have been observed in this series of tests are:

(1) Nitrogen fertilizer applied early in the spring stimulates cool-season grasses but is detrimental to warm-season grasses.

(2) Phosphorus fertilizer increases the stand of legumes where seed is present or is being sown. Both the vigor and the size of seedlings and established plants are increased.

(3) Combinations of nitrogen plus phosphorus fertilizers, especially at the higher rates of nitrogen, decrease legume seedling establishment because of increased grass competition.

(4) Where sweetclover is present, phosphate fertilizer may increase this legume to the extent that it becomes a major problem. Serious reductions of grass yield and stand have been observed to occur under dense stands of second-year sweetclover. The threat is so serious that management of haylands may need to be altered either to control this plant or to better utilize it as forage.

WEED CONTROL

Control of weeds or sweetclover may be desirable for maximum production of good quality hay. In July, 1951, a meadow infested with thistle (*Circium* spp.), perennial sunflower (*Helianthus* spp.) and second-year sweetclover was sprayed with 2,4-D ester. Rates of one-fourth, one-half, and one pound of 2,4-D per acre were applied. All weeds were controlled by the one-half and one-pound rates with the exception of a few colonies of sunflowers, where regrowth occurred. Weed control with 2,4-D presents a real hazard to any legume present and should be used only on those meadows where elimination of the weed is of more importance than the preservation of the legumes.

SUMMARY AND CONCLUSIONS

Four years' data of various fertilizer treatments on subirrigated meadows indicate that hay yields may be increased and hay quality improved by certain practices.

Although grasslands respond to nitrogen, increases in yield may not be great enough to justify the cost. Nitrogen fertilizer either alone or in combination with other fertilizers may retard the establishment of legumes because of increased grass competition.

Phosphorus fertilizer is beneficial in the establishment and maintenance of legumes in subirrigated meadows. Where sweetclover is present, phosphorus fertilization may cause this legume to dominate the vegetation and become a detriment to the grasses.

A combination of nitrogen and phoshorus fertilizers resulted in the greatest increases in hay yields (32 to 254 per cent of nonfertilized plots) in all tests.

Potassium fertilizer applied singly or in combination with other fertilizers had little effect upon yields except in a few cases.

The cost of additional hay produced was lowest where phosphorus fertilizer was applied on meadows containing legumes. Where yields of desirable legumes are increased by the fertilizer, the quality of the hay is improved.

Preliminary results indicate that commercial fertilizers are valuable for increasing hay production on meadows where there are reasonably constant water tables ranging from 6 to 30 inches below the soil surface.

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