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Fertilizer-Induced Changes in Botanical Composition, Yield, and Quality of Native Meadow Hay[1]

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SYNOPSIS. High rates of N and P fertilizers and manure changed the botanical composition and increased hay yields from native flood meadows. Rush and sedge composed 62, 54, 12, and 4% of the hay at 0, 200, 400, and 600 lb. N/acre, while grasses composed 20, 44, 88, and 96% with the same rates of N. Yields of hay were significantly increased with N, P, and manure. The treatments had little effect on the crude-protein content in the hay. Increasing rates of N decreased the P content in the forage.

IN MUCH of the sagebrush-bunchgrass range area, hay production on native meadows is an essential and integral part of the beef-cattle operation. These meadows are flooded naturally for 6 to 12 weeks during the spring and early summer. The flooding period depends on the amount of snowfall that accumulates at higher elevations during the winter and the rate of run-off in the spring.

The vegetative composition of native meadows is primarily determined by flood water. However, the influence of interaction of length and depth of flooding, depth of the water table (4), or the interaction of water with fertilization on botanical composition is not fully understood.

The effect of moderate rates of fertilizer on botanical composition has been studied, and the results indicate that it is possible to alter composition through fertilization. Phosphorus increases the proportion of native legumes which improves hay quality (1, 2, 3). Nitrogen increases the yield of rushes, sedges, and grasses and decreases the yield of legumes (1, 2, 4).

A given meadow type, particularly the rush-sedge-grass or intermediate type meadows (1), varies considerably in composition. The vegetative complex often consists of as many as 85 species in an extremely dense sod. Differential response of these species to fertility levels offers an opportunity to change the botanical composition. This paper presents the results of an experiment designed to study changes in botanical composition through fertilization and to measure the desirability of such changes in terms of hay yield and quality.

MATERIALS AND METHODS

The experiment was conducted on a typical native rush-sedge-grass meadow. Under prolonged inundation the ecological aspect has become one of water-loving species, with rushes (*Juncus* spp.) and sedges (*Carex* spp.) predominating in association with native grasses, legumes, and forbs.

The particular site chosen had received annual applications of 40 pounds of P_2O_5 per acre for several years to increase white-tip clover (*Trifolium variegatum* Nutt.). Permanent plots were established in the fall of 1955. The treatments consisted of annual applications of 0, 200, 400, and 600 pounds of actual N per acre applied as ammonium nitrate; 0 and 240 pounds of P_2O_5 per acre as treble superphosphate; and 0 and 20 tons of manure per acre on a wet-weight basis in factorial combination. Treatments were surface-applied in the fall prior to the harvest year, but will be discussed as if applied in the harvest year. The treatments were assigned at random to 6- by 20-foot plots within each of 4 replications.

Yield data were obtained by harvesting the forage from a strip 38 inches wide throughout the length of each plot. A subsample was removed and dried to determine moisture content, and then ground and subjected to chemical analyses. All yields are reported at 10% moisture content.

Botanical composition was measured by harvesting a strip of forage 2 inches wide and 20 feet long from the edge of the mower swath in replications 1 and 3. The samples were frozen, and later separated by hand into the following species and species groups: White-tip clover (*Trifolium variegatum* Nutt.), beardless wild-rye (*Elymus triticoides* Buckl.), meadow barley (*Hordeum brachyantherum* Nevski), Nevada bluegrass (*Poa nevadensis* Vasey ex Scribn.), rush (*Juncus* spp.), and sedge (*Carex* spp.), and the miscellaneous grass group which was composed largely of annual hairgrass (*Deschampsia danthonioides* (Trin.) Munro ex Benth.), annual beardgrass (*Polypogon monspeliensis* (L.) Dest.), foxtail barley (*Hordeum jubatum* L.), and sloughgrass (*Beckmannia syzigachne* (Steud.) Fern).

Nitrogen content of the hay from all plots in replications 1 and 3 was determined by the Kjeldahl method each year and multiplied by 6.25 to obtain crude protein. Phosphorus content was determined in 1958 and 1959 by the method described by Toth et al. (5).[3]

RESULTS

The fertilizer treatments affected both botanical composition and hay yields. Increasing levels of N increased hay

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[3] Chemical determinations were made by the Department of Agricultural Chemistry, Oregon State College, Corvallis, Oregon.

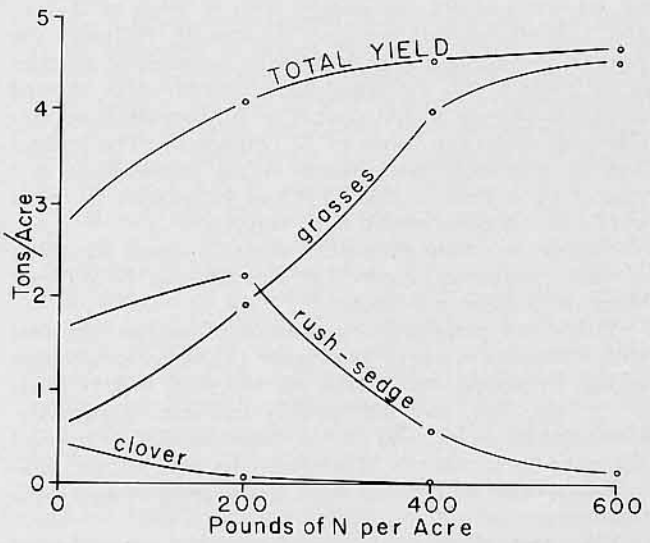

Figure 1—Yields of hay and its species composition in response to nitrogen averaged for phosphorus, manure, and years.

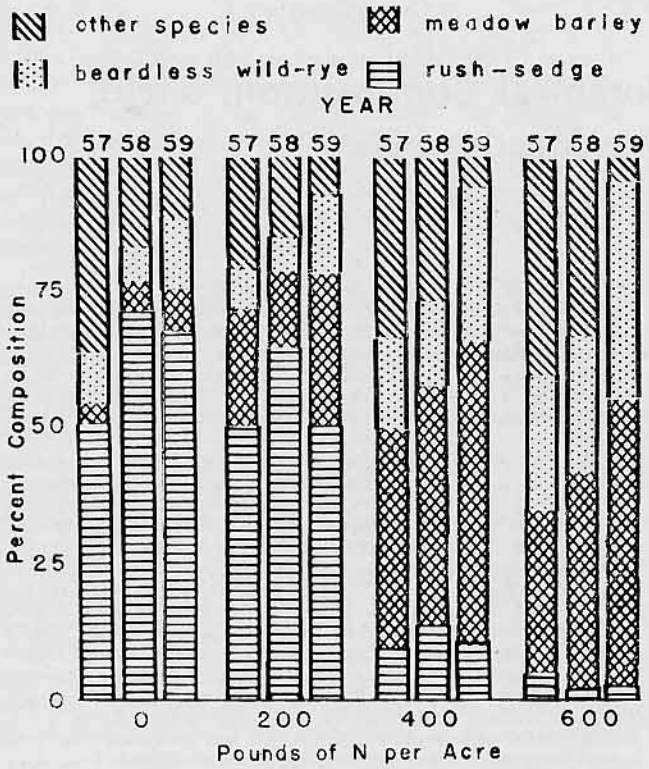

Figure 2—Hay composition during a 3-year period in response to nitrogen averaged for phosphorus and manure.

yields and grass composition of the hay and decreased the rush-sedge and clover composition of the hay (Figure 1).

Botanical Composition

The botanical composition of the sward was divided into six groups composed of either individual species or groups of species. Nitrogen, phosphorus, manure, years, and the (Y)ears × N and N × P interactions all had a significant effect on one or more of these species or species groups.

Response to nitrogen—The percentage composition of rush-sedge decreased with increasing levels of N and was 62, 54, 12, and 4%, by weight, with N levels of 0, 200, 400, and 600 pounds per acre, respectively. Although the percentage composition of rush-sedge decreased at all rates of N (Figure 2), the actual yield of rush-sedge showed an initial increase at 200 pounds of N; then declined rapidly with increasing levels of N (Figure 1). The proportion of rush-sedge was greater in the exceptionally wet year of 1958 than in either 1957 or 1959, with all levels of N except the 600-pound rate (Figure 2).

Nitrogen virtually eliminated white-tip clover regardless of other treatments (Figure 1). This effect of N has been observed in other experiments (1, 2, 4).

Yields and percentage composition of grasses increased with increasing levels of N (Figure 1). Grass composition of hay, by weight, was 20, 44, 88, and 96% with N levels of 0, 200, 400, and 600 pounds per acre, respectively. Grass species and species groups, however, did not respond the same to treatments. Therefore, the ratio of the individual species within the total grass group varied with treatment.

The mean of all treatments showed the proportion of Nevada bluegrass decreased during the 3-year period. It

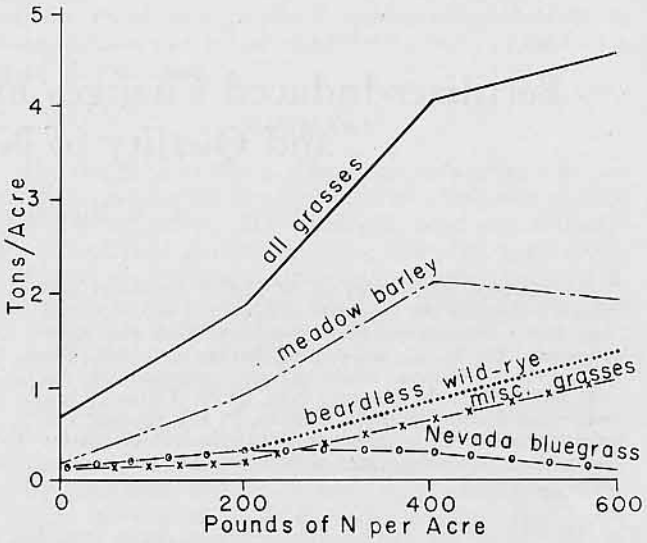

Figure 3—Yields of individual species and species groups in response to nitrogen averaged for phosphorus, manure, and years.

comprised 11% of the hay in 1957, 4.6% in 1958, and 1.6% in 1959. The decrease of this species with time appears to have been caused by applications of N in excess of 400 pounds per acre, although it did show an initial increase with lower rates of N (Figure 3).

The yields of the miscellaneous grass group increased with increasing rates of N (Figure 3). However, it decreased from 17% of the hay in 1957 to 5.3% in 1959. During the 3-year period miscellaneous grasses were apparently replaced by other grass species, with most of the replacement occurring at 400 and 600 pounds of N. Miscellaneous grasses made almost no response to nitrogen in 1959.

Yields of beardless wild-rye were significantly increased with increasing rates of N (Figure 3). While this species responded to N in all 3 years it made its greatest contribution to the total hay yield with 400 and 600 pounds of N per acre in 1959 (Figure 2). With 600 pounds of N in 1959 beardless wild-rye comprised 43% of the weight of the hay, compared with only 25% in 1957. Averaged across all treatments it comprised 14% of the hay in 1957 and 26% in 1959.

Meadow barley made a greater response to N than the other species or species groups. Its yield increased from 0.18 tons with no N to 0.93 and 2.17 tons at 200 and 400 pounds of N, respectively, and then decreased to 1.92 tons at 600 pounds of N (Figure 3). However, the yield of meadow barley at 600 pounds of N depended on the year, resulting in a significant Y × N interaction. The application of 600 pounds of N per acre resulted in a 0.56 ton decrease over the 400 pound rate in 1957, a 0.07 ton decrease in 1958, and essentially no decrease over the 400 pound rate in 1959.

Response to phosphorus—Phosphorus increased the yields of grasses comprising the hay (as well as hay yields) primarily by increasing the yields of meadow barley. Yields of this species were increased an average of 0.6 ton per acre with P.

Phosphorus decreased the yields of rush-sedge in all 3 years, with the greatest reduction occurring in 1957. Yields

Table 1—Effects of nitrogen, phosphorus, and manure on yields of meadow hay averaged for 4 years.

Manure and phosphorus treatments	Pounds of N per acre				Mean
	0	200	400	600	
	Hay yields, tons per acre				
No manure:					
No P_2O_5	2.42	3.82	4.08	4.40	3.68
240 lb. P_2O_5 /acre	3.21	4.30	4.45	4.93	4.22
20 tons manure/acre:					
No P_2O_5	2.81	4.34	5.08	4.95	4.30
240 lb. P_2O_5/acre:	2.82	4.62	4.79	4.53	4.19
Mean	2.82	4.27	4.60	4.70	

Main effects of manure and phosphorus significant at .01 level. LSD for comparing nitrogen means (P. 05) = 0.22 (P. 01) = 0.29

Table 2—Effect of nitrogen on yields of meadow hay over a 4-year period averaged for levels of phosphorus and manure.

Year	Pounds of N per acre				Mean
	0	200	400	600	
	Hay yields, tons per acre				
1956	3.55	4.85	5.34	5.37	4.78
1957	3.05	4.76	4.95	4.68	4.36
1958	2.80	3.80	3.84	4.16	3.65
1959	1.85	3.67	4.26	4.60	3.60
Mean	2.82	4.27	4.60	4.70	
LSD for comparing:	Nitrogen means		Year means		
(P. 05)	0.22		0.15		
(P. 01)	0.29		0.19		

of rush-sedge were reduced 19, 10, and 7% in 1957, 1958, and 1959, respectively, with applications of P.

Phosphorus increased clover composition in the absence of N in 1957, but there was no increase in clover composition with applications of phosphorus in 1958 and 1959 because of poor growth of clover.

Response to manure—Applications of manure increased yields of rush-sedge 0.1 to 0.2 ton per year, but had little effect on yields of perennial grasses. Manure was detrimental to yields of the miscellaneous grass group, which were mostly annuals, and to white-tip clover. Miscellaneous grasses in the hay decreased from 27% in 1957 to 6% in 1958 and 0% in 1959 with applications of manure. Manure may have interfered physically with the germination and establishment of annual grasses and annual clover. The reduction in these species may be responsible for the increased yields of rush-sedge due to lack of competition.

Hay Yield

The yield of hay averaged across years was significantly increased (.01 level) by N, P, and manure. Yields with rates of N of 400 and 600 pounds per acre did not differ significantly (Table 1); however, the yield curve does continue to increase slightly with all levels of N. Increases in yield due to nitrogen fertilization were 1.45, 1.78, and 1.88 tons at rates of 200, 400, and 600 pounds of N per acre when averaged for levels of phosphorus and manure.

Yield increases resulting from N were not as large as normally expected because check plot yields were considerably higher than the 1 to 2 tons/acre usually encountered (2). The abnormally high yields were probably due to previous applications of P since the yield from the check plots continually decreased during the 4-year period. The decline in yield with time was not the same with all levels of N, which resulted in a Y × N interaction significant at the .01 level (Table 2).

Phosphorus significantly increased yields by 0.21 ton per acre when averaged for 4 years (Table 1). This increase was primarily a result of the 0.7 ton per acre increase in 1959 which caused a significant Y × P interaction.

Table 3—Effects of nitrogen, phosphorus, and manure on the crude protein content of meadow hay, averaged for 4 years.

Manure and phosphorus treatments	Pounds of N per acre				Mean
	0	200	400	600	
	Percent crude protein				
No manure:					
No P_2O_5	9.17	8.66	8.19	8.96	8.74
240 lb. P_2O_5 /acre	9.32	7.79	8.26	8.80	8.54
20 tons manure/acre:					
No P_2O_5	8.49	7.46	7.68	8.60	8.05
240 lb. P_2O_5 /acre	8.88	7.21	8.02	8.46	8.14
Mean	8.96	7.78	8.04	8.71	

Main effect of manure significant at .01 level. LSD for comparing nitrogen means (P. 05) = 0.37 (P. 01) = 0.51

Table 4—Effects of nitrogen, phosphorus, and manure on the phosphorus content of meadow hay, averaged for 2 years.

Manure and phosphorus treatments	Pounds of N per acre				Mean
	0	200	400	600	
	Percent phosphorus				
No manure:					
No P_2O_5	0.161	0.126	0.112	0.106	0.126
240 lb. P_2O_5 /acre	0.234	0.220	0.194	0.174	0.206
20 tons manure/acre:					
No P_2O_5	0.196	0.172	0.151	0.144	0.166
240 lb. P_2O_5 /acre	0.232	0.219	0.216	0.198	0.216
Mean	0.206	0.184	0.168	0.155	

Main effects of phosphorus and manure significant at .01 level. LSD for comparing nitrogen means (P. 05) = 0.013 (P. 01) = 0.018

Manure increased yields by 0.29 ton per acre when averaged for N, P, and years (Table 1). The N × (M)anure, Y × M, and P × M interactions were also significant. Manure and P appeared to be equally effective in increasing yield, but the application of both resulted in a slight decrease compared with individual applications.

Hay Quality

The application of N resulted in a decrease in crude protein when compared with the forage from those plots that did not receive N (Table 3). The crude protein content in the hay was at a minimum with 200 pounds of N per acre. Crude protein increased with increasing increments of N above the 200-pound rate; however, it never reached the concentration found in the forage from plots without N.

The crude-protein content in the hay was also significantly reduced (.01 level) by manure when averaged for N, P, and years (Table 3). Phosphorus had no effect on crude protein and the N × P interaction was not significant at the .05 level, although it did approach significance.

The P content in the hay was decreased with N fertilizer and increased with P and manure (Table 4). Nitrogen at 0, 200, 400, and 600 pounds per acre resulted in a P content of 0.206, 0.184, 0.168, and 0.155%, respectively, when averaged for levels of P and manure. Decreasing concentrations of P in the forage with increasing rates of N were more noticeable in the absence of P fertilizer and manure because of the low initial P content (0.161%) from the control treatments (Table 4). Applications of P and manure together were particularly effective in maintaining the P content under increasing levels of N. The P × M interaction was significant.

Application of 240 pounds of P_2O_5 increased the P content by 0.065% when averaged for N, manure, and years. Manure resulted in an increase of 0.050% when calculated in the same manner.

DISCUSSION

The results show that commercial fertilizers can radically change the botanical composition of native meadows. Nitrogen resulted in the greatest change, but phosphorus also had important effects on individual species.

The reduction in rush and sedge as a result of both N and P fertilizers represented a real decrease in the actual yields of these species and not simply a "dilution effect" due to increased yields of grasses.

The increase in total hay yields was very closely associated with increased yields of grasses. The yields of grasses, in turn, reflected the response of meadow barley and beardless wild-rye to the treatments. The aspect at 400 and 600 pounds of N and 240 pounds of P_2O_5 was completely dominated by these 2 species. Furthermore, these 2 grasses under those fertility levels either held their own or gradually increased during the 3 years investigated. Yearly fluctuations in botanical composition were greater at 0 and 200 pounds of N than at 400 and 600 pounds of N.

One might expect yearly applications of high rates of N to result in yearly increases in grass composition. Nitrogen applied at 400 and 600 pounds per acre converted the meadows almost entirely to grass by the second year and no further increase in grass composition was noted. Two hundred pounds of N per acre resulted in a sward that contained only 48% grass at the end of the second year but, as was found with the higher rates of N, no increase in grass composition occurred in subsequent years. These observations suggest that yearly applications of a given rate of N will induce and maintain a grass population specific to that particular rate and year.

Phosphorus at 240 pounds of P_2O_5 per acre resulted in an increase in hay yields, an increase in yields of grasses, and a decrease in yields of rush and sedge. The predominance of rush and sedge on the meadows may be partly due to the low level of available P in these soils.

Twenty tons of manure per acre had relatively little influence on either hay yields or botanical composition. The increase in yields realized from the application of manure would probably not pay for the application cost. However, the manure was of relatively low quality due to the presence of large amounts of bedding material. The nitrogen content was slightly less than 1% on an oven-dry basis.

The hay quality as measured by crude protein was not improved with N. Six hundred pounds of N per acre were necessary to achieve a forage of approximately the same crude protein content as that produced with no N because legumes were present in the absence of N fertilization. On the basis of P content, N was detrimental to hay quality while P and manure improved it. The P content of the forage produced with high levels of N but without P or manure would not meet the P requirement of beef cattle. Phosphorus or manure increased the P content of the forage to an adequate level.

SUMMARY

The effects of nitrogen, phosphorus, and manure on the botanical composition of native flood meadows were studied over a 4-year period. The treatments were also evaluated in terms of yield and quality of the new plant populations.

Annual applications of ammonium nitrate, treble superphosphate, and manure were made in factorial combination at rates of 0, 200, 400, and 600 pounds of N per acre; 0 and 240 pounds of P_2O_5 per acre; and 0 and 20 tons of manure per acre, respectively.

The actual yields of grasses increased with increasing rates of N. At 400 and 600 pounds of N per acre total hay yields were composed almost entirely of grasses. Meadow barley *(Hordeum brachyantherum)* and beardless wild-rye *(Elymus triticoides)* made a greater response than other grasses investigated.

Nitrogen at 200 pounds per acre resulted in an increase in yields of rush and sedge, but at 400 and 600 pounds per acre greatly depressed it. The percent composition by weight of rush and sedge in the hay showed a continual decrease with increasing levels of N.

Yields of hay were significantly increased with N, P, and manure. However, there was no significant difference (.05 level) among rates of 400 and 600 pounds of N per acre.

Nitrogen actually resulted in a decrease in the crude protein content in the forage due to the elimination of whitetip clover with the application of 200 pounds of N per acre, and only a slight increase in crude protein in the grasses with increasing rates of N application.

The phosphorus content in the hay decreased with increasing rates of N and increased with applications of P and manure.

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