A Legume for Native Flood Meadows: II. Phosphorus Fertilizer Requirements for Maintaining Stands of White-Tip Clover (*Trifolium variegatum*)

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A Legume for Native Flood Meadows: II. Phosphorus Fertilizer Requirements for Maintaining Stands of White-Tip Clover (*Trifolium variegatum*)[1]

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SYNOPSIS. Annual applications of 40 pounds of P_2O_5 per acre resulted in nearly maximum yields of mixed clover-rush-sedge hay. Residual phosphorus was adequate for plant growth only if 120 pounds of P_2O_5 per acre or more had been applied in the previous year. Nearly maximum yields were obtained when the phosphorus content of hay was between 0.20 and 0.23%.

THE establishment and maintenance of an annual native legume, white-tip clover *(Trifolium variegatum)*, in native flood meadows has resulted in greatly increased yield and quality of hay. In a previous report (2) methods of establishing this legume and harvest-management practices necessary to its maintenance were discussed. Data showing the influence of this legume upon hay yield and quality were also presented. The present report gives the results of a 3-year experiment initiated to determine the phosphorus fertility requirements for maintaining stands of white-tip clover.

MATERIALS AND METHODS

The study was conducted on a meadow typical of the rush-sedgegrass type (3). Such a meadow is flooded from early April until late June or early July. The vegetation consists principally of rush (*Juncus* spp.) and sedge (*Carex* spp.) with minor amounts of grass and native clover. The growing season of these species is concurrent with the flooding season. One cutting of hay is taken from meadows during July of each year and regrowth is negligible.

The soil of the experimental area was a silty-clay loam and belongs to the Klamath series (6). The surface soil was mildly calcareous and slightly to moderately alkaline. The subsoil was moderately calcareous and somewhat less alkaline. Analyses of soil samples (0–8 inch depth) from the experimental area revealed average values of 766 ppm. of total salts, pH 7.9, and 4.8 ppm. of sodium bicarbonate-soluble phosphorus (8).

White-tip clover density in the experimental area was increased prior to the initiation of the experiment by phosphorus fertilization (40 pounds of P_2O_5 per acre) in conjunction with delayed harvest to allow for seed dissemination in each of 2 years. It was believed that ample hard seed was present in the soil to insure clover stands during the course of the experiment.

The experiment was conducted as a 7 $\times$ 4 $\times$ 3 factorial in which the 3 years (1955, 1956, and 1957) were factors at 7, 4, and 3 levels of P_2O_5 application. A variation of the split-plot design was used, in that the smallest experimental units (1955 treatments) were treated first and subsequent treatments (1956 and 1957 fertilizer treatments) were then superimposed to provide the larger experimental units. This variation of the split-plot design allowed a more precise evaluation of the 1955 treatments and their residual effects. For example, in 1955, when 1956 and 1957 treatments had not yet been applied, 36 replications were available for the evaluation of the 7 fertilizer treatments. The procedure used in laying out the experiment was as follows: Areas for 3 replications, each 120 by 168 feet in size, were staked at the beginning of the experiment. Each replicate was sub-divided into 3 main plots, each 120 by 56 feet in size, which would receive the 1957 treatments. These 3 main plots were then each divided into four 30 by 56-foot sub-plots which later received the 1956 fertilizer treatments. Each of these 4 sub-plots was then divided into seven 8 by 30-foot sub-sub-plots which received the 1955 treatments.

Levels of P_2O_5 application were 0, 40, 80, 120, 160, 200, and 240 pounds per acre in 1955; 0, 40, 80, and 120 pounds per acre in 1956; and 0, 40, and 80 pounds per acre in 1957. Phosphorus was applied as treble superphosphate in the fall preceding each year listed, but will be referred to in the text as applied during the year in which measurement data were taken. Fertilizer was surface applied with a belt-type tractor-mounted spreader.

Yield samples were taken in July in each of the 3 years by harvesting a 38-inch strip throughout the length of each plot. Subsamples were taken from yield samples for the determination of moisture, crude protein, and phosphorus contents of hay. Crude protein was determined by the Kjeldahl method (1) and phosphorus was determined by the method of Kelley et al. (5).

RESULTS AND DISCUSSION

1955 Data—Fertilizer treatments did not significantly affect either yield or crude-protein content of hay in 1955. The average yield and crude-protein content of hay were 2.1 tons per acre and 7.9%, respectively. The lack of response was due partly to the previous fertilizer treatment

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which had been used to increase the stand of clover on this area, and partly to an unusually poor year for the growth of clover. Phosphorus content of hay increased significantly with fertilization and values were .15, .17, .17, .21, .20, .19, and .20%, respectively, for rates of 0, 40, 80, 120, 160, 200, and 240 pounds of P_2O_5 per acre.

Crude-protein content of hay was significantly correlated with phosphorus content of hay ($r = .43$); however, the relation is not one of dependency. Phosphorus content of herbage is increased as a result of greater availability of P_2O_5 in the soil with fertilization. Crude-protein content of herbage is increased as a result of increased clover composition with phosphorus fertilization. The phosphorus content of clover and associated species in Oregon flood meadows is not significantly different.[3]

1956 Data—Yields of hay in 1956 were significantly affected by both 1955 and 1956 fertilizer treatments (table 1). The responses to residual phosphorus from 1955 applications were quite evident on plots which received no treatment in 1956, but were less apparent on those which received additional phosphorus. There was a significant difference in yields between plots receiving no fertilizer in 1956 and those receiving 40, 80, or 120 pounds of P_2O_5 per acre; however, differences among these 3 rates were not significant. The data indicate that 40 pounds of P_2O_5 per acre in 1956 was adequate for achieving maximum yield response regardless of previous fertilizer treatment. Residual phosphorus from 1955 applications was adequate for maximum growth only when 120 pounds P_2O_5 per acre or more had been applied.

The P content of hay in 1956 was directly related to fertilizer application rates in 1955 and 1956 (table 1). On plots fertilized only in 1955, P content and yield were closely correlated ($r = 0.98$). New applications in 1956 nullified this correlation because 40 pounds of P_2O_5 gave nearly maximum yields although P content of hay continued to increase with higher fertilization rates. Maximum yields were obtained when P content was 0.20% or more.

Crude protein content of hay was significantly increased by 1956 phosphorus applications on those plots which had received no phosphorus or only light applications in 1955, but was not significantly affected on those plots which had received 200 or 240 pounds of P_2O_5 in 1955, (table 1). On plots not fertilized in 1956, crude protein increased in proportion to the amount of phosphorus applied in 1955, with the maximum response occurring at the 200-pound rate. An application of 40 pounds of P_2O_5 per acre in each year was sufficient to obtain an optimum crude-protein content. The increase in crude-protein content may be attributed to increased proportion of clover in the hay, as the two have been shown previously to be closely related (4). Crude-protein and phosphorus contents were again highly correlated ($r = .70$).

1957 Data—Yields of hay in 1957 as affected by phosphorus applications in each of the 3 years are shown in table 2. Average yields were 2.3, 2.6, and 2.8 tons per acre with 0, 40, and 80 pounds of P_2O_5 applied per acre in 1957; however, on those plots which had received no fertilizer in either 1955 or 1956, yields were 1.7, 2.0, and 2.6 tons per acre with 0, 40, and 80 pounds of P_2O_5 per acre. The larger yields on those plots previously fertilized is indicative of the response to residual phosphorus.

The influence of fertilization, in each of 3 years, upon the phosphorus content of hay in 1957 is shown in table 3. Differences for the three 1957 treatments were not significant although the trend was for phosphorus content to increase with increasing fertilizer. The lack of significance is partly due to a limited number of degrees of freedom for

[3] Cooper, C. S. Unpublished data.

Table 1—Influence of 1955 and 1956 fertilizer treatments upon the yield, crude protein content, and phosphorus content of hay in 1956.

P_2O_5 in 1956	Pounds P_2O_5 per acre in 1955							
	0	40	80	120	160	200	240	Aver.
lb./A.			Hay yields in 1956, tons per acre					
0	2.4	2.6	2.8	3.0	2.8	3.1	3.0	2.8
40	3.0	3.2	3.3	3.1	3.0	3.1	3.2	3.1
80	3.2	3.2	3.1	3.2	3.0	3.2	3.4	3.2
120	3.0	3.0	3.2	3.2	3.2	3.1	3.1	3.1
Aver.	2.9	3.0	3.1	3.1	3.0	3.1	3.2	
			Percent crude protein in hay in 1956					
0	8.3	9.0	8.8	9.9	9.6	11.8	11.2	9.8
40	10.7	11.0	9.9	11.0	11.8	11.2	10.1	10.8
80	10.7	9.9	11.2	11.7	11.4	10.4	10.2	10.8
120	11.4	11.3	10.1	11.1	10.7	10.9	11.2	11.0
Aver.	10.3	10.3	10.0	11.0	10.9	11.1	10.7	
			Percent phosphorus in hay in 1956					
0	.14	.16	.18	.20	.19	.23	.22	.19
40	.19	.23	.21	.21	.24	.26	.25	.23
80	.22	.21	.25	.25	.27	.24	.27	.25
120	.25	.24	.23	.26	.26	.27	.27	.26
Aver.	.20	.21	.22	.23	.24	.25	.25	

Standard errors for comparing differences:	Yield	Protein	Phosph.
Among 1955 treatment means	.10T/A	NS	.01%
Among 1956 treatment means	.14T/A	NS	.01%
Btw. 1955 tr. means at 1 level of 1956 treatment	NS	.8%	NS
Btw. 1956 tr. means at 1 level of 1955 treatment	NS	.9%	NS

Table 2—Yields of hay in 1957 as affected by fertilizer treatments in 1955, 1956, and 1957.

Lb. P_2O_5/A. 1957	1956	Pounds P_2O_5 per acre in 1955: 0	40	80	120	160	200	240	Aver.
				Hay yields in 1957, tons per acre					
0	0	1.7	1.8	1.9	2.2	2.0	2.6	2.0	2.0
	40	1.7	2.5	2.7	2.4	2.0	2.9	2.5	2.4
	80	2.5	2.6	2.7	2.2	2.2	2.7	2.9	2.5
	120	2.6	2.5	2.2	2.1	2.4	2.3	2.9	2.4
	Aver.	2.1	2.4	2.4	2.2	2.2	2.6	2.6	2.3
40	0	2.0	2.8	2.4	1.9	2.6	2.5	2.8	2.4
	40	2.7	2.6	2.8	2.4	2.6	2.6	3.0	2.7
	80	2.6	2.7	2.4	3.0	2.7	3.0	3.3	2.8
	120	2.4	2.4	2.9	2.8	2.5	2.4	2.3	2.5
	Aver.	2.4	2.6	2.6	2.5	2.6	2.6	2.8	2.6
80	0	2.6	2.6	2.8	2.8	3.1	2.9	3.0	2.8
	40	2.6	2.6	2.8	2.7	2.7	2.7	2.6	2.7
	80	2.5	2.4	2.6	2.8	2.5	2.8	2.9	2.6
	120	2.8	2.8	3.4	2.9	2.7	3.0	2.6	2.9
	Aver.	2.6	2.6	2.9	2.8	2.8	2.8	2.8	2.8

Standard errors for comparing:
1957 treatment yield average = 0.2 ton.
1955 treatment yield averages within 1 level of 1957 treatment = 0.1 ton.
1957 treatment yield averages within 1 level of 1955 treatment = 0.1 ton.

Table 3—Phosphorus content of hay in 1957 as influenced by fertilizer treatment in 1955, 1956, and 1957.

Lb. P_2O_5/A. 1957	1956	Pounds P_2O_5 per acre in 1955: 0	40	80	120	160	200	240	Aver.
				Percent phosphorus in hay in 1957					
0	0	.17	.19	.18	.19	.18	.22	.21	.19
	40	.19	.19	.20	.20	.22	.21	.24	.21
	80	.20	.21	.23	.25	.24	.24	.23	.23
	120	.22	.23	.25	.27	.23	.25	.24	.24
	Aver.	.20	.20	.22	.23	.22	.23	.23	.22
40	0	.20	.21	.21	.22	.23	.24	.25	.22
	40	.21	.21	.21	.22	.23	.23	.23	.22
	80	.22	.23	.26	.23	.25	.24	.25	.24
	120	.24	.23	.23	.24	.26	.25	.27	.24
	Aver.	.22	.22	.23	.23	.24	.24	.25	.23
80	0	.24	.24	.24	.28	.24	.25	.26	.25
	40	.24	.24	.25	.24	.25	.28	.25	.25
	80	.23	.22	.25	.23	.25	.28	.26	.24
	120	.24	.27	.24	.26	.24	.28	.29	.26
	Aver.	.24	.24	.24	.25	.24	.27	.26	.25

Table 4—Crude protein content of hay in 1957 as influenced by fertilizer treatments in 1955, 1956, and 1957.

Lb. P_2O_5 /A.		Pounds P_2O_5 per acre in 1955							
1957	1956	0	40	80	120	160	200	240	Aver.
		Percent crude protein in hay in 1957							
0	0	8.0	8.2	7.6	7.5	8.1	8.3	8.4	8.0
	40	8.2	7.8	8.3	8.6	8.4	8.7	8.6	8.4
	80	8.2	8.3	9.1	8.5	8.2	8.4	9.1	8.5
	120	7.6	8.8	8.4	9.6	9.1	8.6	9.5	8.8
	Aver.	8.0	8.3	8.3	8.6	8.4	8.5	8.9	8.4
40	0	8.6	8.0	8.7	8.4	8.3	8.6	8.6	8.4
	40	8.2	8.4	8.3	8.1	8.1	8.6	8.8	8.4
	80	8.7	8.8	8.0	8.8	9.0	10.4	9.2	9.0
	120	8.0	9.1	9.4	9.8	8.3	8.5	8.2	8.8
	Aver.	8.4	8.6	8.6	8.8	8.4	9.0	8.7	8.6
80	0	9.2	9.2	7.7	8.9	7.7	8.7	8.9	8.6
	40	8.0	8.3	8.6	8.9	9.0	8.2	8.8	8.5
	80	8.4	9.2	8.8	8.8	8.2	8.5	8.2	8.6
	120	9.4	9.7	9.3	9.6	9.7	9.5	9.8	9.6
	Aver.	8.8	9.1	8.6	9.1	8.6	8.7	8.9	8.8

error in evaluating 1957 treatments and to the masking effect of residual phosphorus from applications in previous years. Residual phosphorus from both the 1955 and 1956 fertilizer treatments significantly affected the phosphorus content of hay in 1957, in proportion to the amount of phosphorus applied in those years.

The crude protein contents of 1957 hay as affected by fertilizer treatment in each of the 3 years are presented in table 4. Differences among crude protein values were not significant; however, the trend was for crude protein to increase in proportion to the amount of phosphorus applied. The lack of significance is due partly to the fact that samples from only two replications were used in the chemical analyses for crude protein, which reduced the number of degrees of freedom for error in the statistical analyses. In addition, the accumulative effect of residual phosphorus tended to mask the effects of the 1957 treatments. Crude protein and phosphorus contents of hay in 1957 were significantly correlated ($r = .74$).

Year Differences—Average yields were 2.1, 3.0, and 2.6 tons per acre, and average crude-protein contents were 7.9, 10.6, and 8.6%, respectively, in 1955, 1956, and 1957. These data show the close relation between clover composition as reflected by crude protein contents, and yield. Year differences were most profound in terms of clover density. The density of clover in any year is largely dependent upon the effect of early spring temperatures and flood conditions upon its establishment (2); however, yields of established plants are largely dependent upon P_2O_5 fertilization. When temperatures are low, particularly in April, clover seedlings do not make much growth prior to flooding and are readily killed by complete submergence. Average monthly temperatures in April were 38.5, 46.9, and 45.2° F. and in May were 50.0, 54.9, and 53.8°, respectively, in 1955, 1956, and 1957. Yields and crude protein contents of hay during the 3 years were proportional to these temperatures.

DISCUSSION AND CONCLUSIONS

On the site studied, which is representative of much of the area of native flood meadows in Oregon, an annual application of 40 pounds of P_2O_5 per acre is adequate for nearly maximum yields of mixed clover-rush-sedge hay. More efficient use of phosphorus is made with annual applications than with large applications in one year to supply the phosphorus requirements of the clover for several years.

The phosphorus content of herbage when yields were near the maximum was between 0.20 and 0.23%. It would appear that the phosphorus content of hay may be used as a criterion for determining whether a soil is providing adequate available soil phosphorus for the growth of clover. A phosphorus content of 0.20% or more also provides the recommended allowance for wintering beef cattle (7).

The crude protein content of flood-meadow hay is a reflection of the proportion of clover in the sward (4). Differences in crude protein content were most evident among years and were directly related to differences in temperature and flood conditions among years and their effects upon establishment of clover seedlings. In the temperature-flooding relationship, one cannot control temperature; however, the beginning date of flooding can and should be delayed in many areas to permit clover seedlings to become well established.

SUMMARY

Phosphorus fertility requirements for maintaining stands of white-tip clover in native flood meadows were studied in a factorial experiment over a 3-year period. Yield, protein content, and phosphorus content of hay were measured each year.

Annual applications of 40 pounds of P_2O_5 per acre resulted in nearly maximum yields of mixed clover-rush-sedge hay. Residual phosphorus was adequate for plant growth only when 120 pounds of P_2O_5 per acre or more had been applied in the previous year.

Phosphorus content of hay increased in proportion to the amount of P_2O_5 applied. Nearly maximum yields were obtained when the phosphorus content of hay was between 0.20 and 0.23%. A phosphorus content of this magnitude is realized with annual applications of 40 pounds of P_2O_5 per acre.

Phosphorus fertilization increased crude protein indirectly as a result of an increased proportion of clover in the hay. Differences in the proportions of clover in the hay were marked among years and were related to early spring temperatures and flood conditions. When possible, the beginning date of flooding should be delayed to permit clover seedlings to become well established. Flooding may be controlled in some areas during the early season when the runoff is light.

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