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Effect of Method of Phosphorus Application On Alfalfa Grown on a Willamette Valley "Red Hill" Soil

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SUMMARY AND CONCLUSIONS

An experiment was established in 1957 to evaluate the effect of applications of lime and rate, time, and method of phosphorus (P)[1] application on the yield and P content of alfalfa when grown on a reddish brown lateritic ("Red Hill") soil in the Willamette Valley. Rates of 2 and 6 tons of lime/A were applied before establishment. Applying all of the P at or before planting was compared with annual applications of P. Rates of 60, 180, and 360 pounds of phosphate (P_2O_5)/A (26, 79, and 157 pounds phosphorus, P/A)[2] were applied during the 3-year period.

Small, but significant, responses were measured from application of P and the following conclusions can be drawn:

1. There was a marked benefit on seedling vigor and stand establishment from banding P 1 inch below the seed at planting.
2. Band and broadcast applications of P at planting time produced the same yield of hay after the stand became established.
3. Annual applications of P were equal to or better than applying all of the P at planting time after the first year of hay yields.
4. The 6-ton rate of lime did not increase the availability of P over the 2-ton rate of lime.

INTRODUCTION

Phosphorus "fixation" and the effect of liming to increase the availability of soil P has been recognized as an important soil management practice on acid lateritic soils where P "fixation" is a problem. The "Red Hill" soils in western Oregon are an excellent example of this problem.

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[1] Phosphorus will be referred to as P throughout this paper.

[2] Fertilizer guarantees are given as P_2O_5. Multiply P by 2.29 to equal P_2O_5.

The reddish brown lateritic or "Red Hill" soils in the Willamette Valley have a marked P "fixing capacity" (2,6).[3] Phosphorus deficiency is frequently an important factor limiting the yields of many crops grown on these soils (4,5).

The response of different legume species to lime and P and the lime x P interactions evident in an experiment established at the Red Soils Experiment Station in 1954 prompted the establishment of the experiment reported in this publication. This experiment was established at the Red Soils Experiment Station in the spring of 1957 with the following objectives: To evaluate the effect of 1) lime applications; 2) time of P application; and 3) method of P application on a) lime x P interactions, b) yield of alfalfa hay, and c) the P content of alfalfa.

EXPERIMENTAL PROCEDURE

The experimental site was located on the Red Soils Experiment Station at Oregon City. The soil has been mapped as Olympic silt loam in published soil survey reports (3). The soil profile description is given in the appendix.

Soil samples were taken from each replication before establishment of the experiment and analyzed using the procedures of the Oregon State University soil testing laboratory (1). Phosphorus was extracted with sodium bicarbonate using Olsen's procedure. Exchangeable bases were extracted with a one normal ammonium acetate solution buffered at pH 7.0 using a 1:10 soil to solution ratio. The following analyses were obtained: Soil pH 5.4, 9 lb. P/A, 100 lb. K/A or .13 me K/100g, 5 me Ca/100g, 1.3 me Mg/100g, 16 me CEC/100g.

The area had been in production of alta fescue grass seed or hay for a period of years prior to the establishment of the experiment. The area was summer fallowed during the summer of 1956 to allow time for the alta fescue sod to decompose.

The lime treatments were applied in the fall of 1956 and disked into the surface 4 to 6 inches of soil. This allowed time for the lime to react with soil acids before the alfalfa was seeded. Limestone (95% $CaCO_3$) ground so that 96% would pass a 40-mesh sieve and 85% would pass a 100-mesh sieve was used.

DuPuits alfalfa was seeded in rows 8 inches apart with a drill that was capable of banding the fertilizer 1 to $1\frac{1}{2}$ inches directly below the seed at planting time. The seed was inoculated before planting and satisfactory nodulation was obtained on all treatments.

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[3] Numbers in parentheses refer to literature cited.

The following treatments were established in a complete 2x2x2x2 factorial arrangement: 1) Two or six tons of lime/A, 2) 60 or 120 pounds of phosphate (P_2O_5)/A (26 or 52 pounds P/A) each year vs. 3) 180 or 360 pounds of phosphate (P_2O_5)/A (79 or 157 pounds P/A) applied at planting, and 4) the P disked into the seedbed before planting or banded directly under the seed at planting. Additional treatments were added to include 1) phosphate applications at 60 pounds of phosphate (P_2O_5)/A (26 pounds P/A) at planting for both rates of lime and both methods of application, 2) the 2 and 6 ton/A rate of lime without P, 3) one complete check plot, and 4) one treatment that included only the blanket application of 150 pounds potash (K_2O)/A, (125 pounds K/A)[4] 2 pounds boron B/A, and 30 pounds sulfur/A. This blanket application of KBS was applied to all lime and P treatments each fall.

Table 1. Arrangement of Lime and Phosphorus Treatments

Rate of lime and phosphate			Time and method of P application				
				Single application at planting		Total for three applications	
Lime *T/A*	P_2O_5- *Lb/A*	(P) *Lb/A*	None	Broadcast	Band	Broadcast	Band plus Broadcast
2	0	(0)	3*				
2	60	(26)		5	8		
2	180	(79)		6	9	17	19
2	360	(157)		7	10	18	20
6	0	(0)	4				
6	60	(26)		11	14		
6	180	(79)		12	15	21	23
6	360	(157)		13	16	22	24

* Treatment numbers used in discussion and tables.

All treatments except a check (treatment no. 1) received blanket applications of 150 pounds potash (K_2O/A) (125 pounds K/A), 2 pounds boron/A, and 30 pounds sulfur/A each year.

Concentrated super phosphate, muriate of potash, agricultural grade borax, and gypsum were used as sources of fertilizer materials.

An excellent stand of weed-free alfalfa was obtained on all plots seeded in May 1957.

Two cuttings of alfalfa were harvested each year. The first cutting was harvested between May 15 and 30 and the second between

[4] Fertilizer guarantees are given as K_2O. Multiply K by 1.2 to equal K_2O.

July 5 and 10. Moisture samples were taken on each plot to convert plot green weights to pounds of oven-dry hay per acre. The shallow soil depth (3 feet) and the dry summers eliminated the possibility of a third cutting.

Plant samples were taken on the first cutting during 1959, 1960, and 1961. The top half of the plant was taken to avoid soil contamination and some leaf loss that occurred on the plots that were lodged from heavy growth of the alfalfa.

The alfalfa did not start blooming before the first cutting; this meant that plant samples were not taken in relation to a specific stage of bloom.

RESULTS AND DISCUSSION

There was a marked response from band application of P during the summer of establishment. The photograph in Figure 1, taken during July 1957, compares a band with a broadcast application of P. It was evident that greater seedling vigor of alfalfa was obtained

Figure 1. The effect of banding P on seedling vigor of alfalfa. The plot on the left was P banded 1 inch below the seed. The plot on the right was P broadcast.

with 60 pounds of phosphate (P_2O_5)/A (26 pounds P/A) banded directly under the seed at planting than with 360 pounds of phosphate (P_2O_5)/A (157 pounds P/A) disked in before planting. The lime treatments did not have any visible effect on seedling vigor.

Effects of Lime Treatments

Lime increased the yield[5] of alfalfa throughout the four years of the experiment with maximum increases coming during the first and second year of hay production. Treatments three and four can be compared with treatment two (Table 2) to evaluate the effect of lime without P.

Table 2. The Effect of Lime on the Yield of Alfalfa

Trt. No.	Trt.	1958 yield	1959 yield	1960 yield	Av. 58-60 yield	1961 yield
		lb/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*
2	L_0 P_0	4,150	6,040	7,040	5,740	6,130
3	L_2 P_0	6,750	8,460	8,240	7,820	5,680
4	L_6 P_0	6,400	8,610	8,550	7,850	7,610

L_2, L_6 = 2 and 6 tons lime/A applied September 1956.

There was no significant difference between the 2- and 6-ton lime rates (treatment 3 vs. 4) until 1961—the 4th years' yield data. This difference between rates of lime was not evident with optimum P (Table 3) fertilization. Treatments 17 through 20 can be compared with treatments 21 through 24 to evaluate this effect. The phosphorus response that was evident after the first year (by comparing treatments 3 and 4 in Table 2 with the yield data in Table 3) probably contributed to the lime by phosphorus interaction in 1961.

Table 3. The Effect of Lime with P on the Yield of Alfalfa

Trt. No.	Trt.	1958 yield	1959 yield	1960 yield	Av. 58-60 yield	1961 yield
		lb/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*
17-20	L_2 P*	6,640	10,010	9,090	8,570	8,470
21-24	L_6 P*	6,670	10,090	8,860	8,540	7,990

P* average for plots receiving annual applications of P.

[5] The treatments with statistically significant increases in yield will be noted.

The 3-year average yield for the treatments receiving P and 2 tons of lime per acre was 8,580 compared with 8,540 for the treatments receiving P and 6 tons of lime per acre. The yield during 1960 and 1961 was slightly higher for the treatments receiving a combination of 2 tons of lime per acre and 3 annual applications of P.

Effects of Phosphorus Treatments

The first year of hay production showed a significant response (Table 4) from P only on those treatments receiving 180 (trts. 6, 7, 12, 13) or 360 pounds (trts. 9, 10, 15 ,16) of phosphate (P_2O_5)/A (79 or 157 pounds P/A) at establishment. This increase was relatively small, varying from 950 to 1,250 pounds per acre, and the difference between methods of P application was not significant on the first years' yield data.

Table 4. The Effect of Method of P Application on the Yield and P Content of Alfalfa

Trt. No.	Trt.	Effects of treatment on yield and P content of alfalfa hay					
		1958 yield	1959 yield	1959 P	1960 yield	1960 P	Av. yield
		lb/A	*lb/A*	*%*	*lb/A*	*%*	*lb/A*
3, 4	P_o	6,580	8,540	.26	8,400	.21	7,840
5, 11	P_1 br	6,240	8,440	.25	7,790	.18	7,490
8, 14	P_1 ba	6,270	9,100	.26	8,100	.19	7,820
6, 7, 12, 13	P* br	7,590	9,950	.32	8,840	.22	8,790
9, 10, 15, 16	P* ba	7,700	10,100	.30	8,700	.22	8,830

The 2 and 6 ton lime rates were averaged.
P br or ba = phosphorus broadcast (br) or banded (ba) at planting.
P_1, P* = 60 or *(the average of 180 and 360) pounds phosphate (P_2O_5)/A (79 pounds and 157 pounds P/A).

These effects were a marked contrast to the response of alfalfa seedlings to band applications of P noted in Figure 1.

All P treatments except those receiving 60 pounds of phosphate (P_2O_5)/A (26 pounds P/A) at establishment only (trts. 5, 11, 8, 14) showed a significant response from P in 1959. The increase in yield from the higher rates of P varied from 1,400 to 1,600 pounds of hay per acre.

The method of phosphorus application had no significant effect on the plots showing a response from phosphorus during 1958 through 1960. Treatments 6 and 12 versus 9 and 15 or 7 and 13 versus 10 and 16 evaluate this effect in Table 5.

Table 5. THE EFFECT OF METHOD AND RATE OF APPLICATION ON YIELD OF ALFALFA

Trt. No.	Trts.	The effect of treatments on yield of alfalfa hay 1958 yield	1959 yield	1960 yield	Av. 58-60 yield	1961 yield
		lb/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*
2	L_0P_0	4,150	6,040	7,040	5,740	6,130
3, 4	L* P_0	6,580	8,540	8,400	7,840	6,650
		Av. for single P application at planting				
6, 12	L* P_3 br	7,420	9,930	8,740	8,690	7,680
9, 15	L* P_3 ba	7,660	9,840	8,780	8,760	8,090
7, 13	L* P_6 br	7,760	9,970	8,940	8,890	7,810
10, 16	L* P_6 ba	7,740	10,370	8,620	8,910	8,420

L* The 2 and 6 ton lime rates were averaged.
P_3, P_6 = Total of 180 or 360 lbs. phosphate (P_2O_5)/A (79 or 157 pounds P/A) applied.
br, ba = broadcast or banded at planting.

The plots receiving annual applications of phosphorus (Table 6) had a lower yield in 1958. This is actually a reflection of rate of application since treatments 6 through 16 received the total application of phosphorus during 1957. However, all plots receiving annual applications of phosphorus had equal or higher yields during 1960 and 1961 than the plots receiving comparable rates of phosphorus in one application. This would indicate that any advantage from band application or heavy initial applications of P would have to occur during stand establishment and the first year of hay production.

Table 6. THE EFFECT OF TIME OF P APPLICATION ON YIELD OF ALFALFA

Trt. No.	Trts.	The effects of treatments on yield of alfalfa hay 1958 yield	1959 yield	1960 yield	Av. 58-60 yield	1961 yield
		lb/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*
		Av. for single P application at planting				
6, 12, 9, 15	L* P_3	7,540	9,890	8,760	8,730	7,890
7, 13, 10, 16	L* P_6	7,750	10,170	8,780	8,900	8,120
		Av. for three annual applications of P				
17, 19, 21, 23	L* P_3	6,450	9,990	8,990	8,470	8,120
18, 20, 22, 24	L* P_6	6,850	10,110	8,960	8,640	8,330

L* the 2 and 6 ton lime rates were averaged.
P_3, P_6 = total of 180 or 360 lbs. phosphate (P_2O_5)/A (79-157 pounds P/A) applied.

Treatments 6 through 16 can be compared with treatments 17 through 24 to evaluate annual applications versus a single application of the same total rate of P at planting.

In summary, the three years data show a significant response to lime and P. The method of P application did not have any significant effect on yield, but time of application did have a significant effect on yield. This is reflected in the response from the higher rates of P during 1958 and the greater 1961 residual effect from those treatments receiving 120 pounds of phosphate (P_2O_5)/A in 1957, 1958, and 1959.

Effect of Lime and Fertilizer Treatments on Phosphorus Content of Alfalfa

The effect of the lime and fertilizer treatments on the P content of the alfalfa is given in Table 7 and Appendix Table 2. Comparisons should not be made between treatments 5 through 16 and treatments 17 through 24 in 1959 since all of the P had been applied to the first group of treatments while two-thirds of the P had been applied to the second group of treatments. Also, detailed comparisons should not be made between the P contents for the different years since plant samples were taken at different stages of maturity in 1959 than in 1960 and 1961. The stage of maturity and difference in the growing season undoubtedly accounts for the higher P content in 1959. This effect was evident on all treatments that did not receive P.

Table 7. The Effect of Time and Method of Application on the P Content of Alfalfa

Trt. No.	Trt.	The effect of treatments on P content of alfalfa		
		1959	1960	1961
		% P	*% P*	*% P*
2	$L_0 P_0$	.25	.17	.19
3, 4	L* P_0	.29	.21	.21
		Av. for single P application at planting		
6, 12	L* P_3 br	.31	.20	.24
9, 15	L* P_3 ba	.28	.22	.22
7, 13	L* P_6 br	.32	.24	.24
10, 16	L* P_6 ba	.32	.22	.24
		Av. for three annual applications of P		
17, 19, 21, 23	L* P_3	.29	.22	.22
18, 20, 22, 24	L* P_6	.31	.26	.26

* The 2 and 6 ton lime rates were averaged.
P_3, P_6 = total of 180 or 360 lbs. phosphate (P_2O_5)/A (79 or 157 pounds P/A).
br, ba = broadcast or banded at planting.

Phosphorus fertilization resulted in an increase in the P content of the alfalfa in 1959, 1960 and 1961 (Table 7 and Appendix Table 2). By 1960 all plots had received the full application of P and comparisons can be made between applying the three-year application at or before planting with annual applications.

The 1960 and 1961 data show higher P contents when P was applied in annual applications compared with the application of the same total rate of P at planting time (Table 7).

It was evident that the plots receiving 120 pounds of phosphate (P_2O_5)/A each year had the highest P contents. The rate of lime in treatments 5 through 24 and the method of P application did not have any effect on P contents in 1960 and 1961.

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APPENDIX

Appendix Table 1. THE EFFECT OF TIME, RATE, AND METHOD OF PHOSPHORUS APPLICATION AND RATE OF LIME APPLICATION ON THE YIELD OF ALFALFA

	Treatments*				Yield of hay (Oven dry)				
		Phosphorus							
	Lime T/A	P_2O_5 lb/A	(P lb/A)	Method	1958	1959	1960	Av. 58-60	1961
					lb/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*
1	0	0			4,040	5,040	5,660	4,910	5,210
2	0	0			4,150	6,040	7,040	5,740	6,130
3	2	0			6,750	8,460	8,240	7,820	5,680
4	6	0			6,400	8,610	8,550	7,850	7,610
	Average for treatments 3 and 4				6,580	8,540	8,400	7,840	6,650
				Single application of phosphorus at planting time					
5	2	60	(26)	Broadcast	6,270	8,120	7,830	7,410	6,880
6	2	180	(79)	Broadcast	7,420	9,790	8,350	8,520	7,400
7	2	360	(157)	Broadcast	7,900	10,060	8,760	8,910	7,340
	Average for treatments 6 and 7				7,660	9,930	8,550	8,720	7,370
8	2	60	(26)	Band	6,010	8,700	7,960	7,560	7,060
9	2	180	(79)	Band	7,360	9,960	8,430	8,580	7,850
10	2	360	(157)	Band	7,770	10,400	8,230	8,800	8,640
	Average for treatments 9 and 10				7,570	10,180	8,330	8,690	8,250
11	6	60	(26)	Broadcast	6,200	8,750	7,740	7,560	6,950
12	6	180	(79)	Broadcast	7,410	10,060	9,130	8,870	7,970
13	6	360	(157)	Broadcast	7,610	9,880	9,110	8,870	8,280

15	6	180	(79)	Band	7,950	9,710	**9,120**	8,950	8,020
16	6	360	(157)	Band	7,700	10,330	**9,010**	9,010	8,190
	Average for treatments 15 and 16				7,830	10,020	**9,070**	8,970	8,260
	Total for three annual applications of phosphorus								
17	2	180	(79)	Broadcast	6,610	10,030	9,330	8,660	8,440
18	2	360	(157)	Broadcast	6,440	10,130	8,840	8,470	7,800
	Average for treatments 17 and 18				6,530	10,080	9,090	8,570	8,120
19	2	180	(79)	Band + broadcast	6,520	9,790	8,930	8,410	8,330
20	2	360	(157)	Band + broadcast	6,950	10,070	9,240	8,750	9,290
	Average for treatments 19 and 20				6,740	9,930	9,090	8,580	8,810
21	6	180	(79)	Broadcast	6,430	10,350	8,710	8,500	7,920
22	6	360	(157)	Broadcast	7,020	9,930	9,040	8,660	8,120
	Average for treatments 21 and 22				6,730	10,140	8,880	8,580	8,020
23	6	180	(79)	Band + broadcast	6,220	9,780	8,970	8,320	7,800
24	6	360	(157)	Band + broadcast	6,980	10,300	8,710	8,660	8,110
	Average for treatments 23 and 24				6,600	10,040	8,840	8,490	7,960

* All treatments except No. 1 had 150 lbs. K_2O/A (125 lbs. K/A), 2 lbs. B/A, and 30 lbs. S/A.

LSD .05 any 2 treatments	1,175	1,000	1,000
.01 any 2 treatments	1,560	1,340	1,340
LSD .05 for averages from 2 trts.	626	720	710
.01 for averages from 2 trts.	830	960	940
Coefficient of variance	12.4%	7.6%	10.6%

Appendix Table 2. The Effect of Time, Rate, and Method of Phosphorus Application and Rate of Lime Application on the Phosphorus Content of Alfalfa

	Treatments*				Phosphorus in alfalfa tops		
			Phosphorus				
	Lime T/A	P_2O_5 lb/A	(P lb/A)	Method	1959** % P	1960 % P	1961 % P
1	0	0			0.22	0.16	0.18
2	0	0			.25	.17	.19
3	2	0			.26	.21	.21
4	6	0			.32	.20	.21
	Average for treatments 3 and 4				.29	.21	.21
	Single application of phosphorus at planting						
5	2	60	(26)	Broadcast	.24	.18	.21
6	2	180	(79)	Broadcast	.31	.20	.24
7	2	360	(157)	Broadcast	.33	.23	.25
	Average for treatments 6 and 7				.32	.22	.25
8	2	60	(26)	Banded	.27	.18	.21
9	2	180	(79)	Banded	.27	.21	.23
10	2	360	(157)	Banded	.33	.23	.23
	Average for treatments 9 and 10				.30	.22	.23
11	6	60	(26)	Broadcast	.26	.18	.21
12	6	180	(79)	Broadcast	.31	.20	.23
13	6	360	(157)	Broadcast	.30	.24	.23
	Average for treatments 12 and 13				.31	.22	.23
14	6	60	(26)	Banded	.24	.20	.23
15	6	180	(79)	Banded	.29	.22	.21
16	6	360	(157)	Banded	.30	.21	.25
	Average for treatments 15 and 16				.30	.22	.23
	Total for three annual applications of phosphorus						
17	2	180	(79)	Broadcast	.31	.23	.22
18	2	360	(157)	Broadcast	.31	.24	.24
	Average for treatments 15 and 16				.30	.22	.23
19	2	180	(79)	Band + broadcast	.34	.22	.22
20	2	360	(157)	Band + broadcast	.27	.26	.26
	Average for treatments 19 and 20				.31	.24	.24
21	6	180	(79)	Broadcast	.29	.23	.22
22	6	360	(157)		.33	.26	.27
	Average for treatments 21 and 22				.31	.25	.25
23	6	180	(79)	Band + broadcast	.23	.21	.22
24	6	360	(157)	Band + broadcast	.32	.26	.27
	Average for treatments 23 and 24				.32	.24	.25

* All treatments except No. 1 received 150 lbs. K_2O/A (125 lbs. K/A), 2 lbs. B/A, and 30 lbs. S/A.

LSD .05 any 2 treatments	.024	.028
.01 any 2 treatments	.032	.038
LSD .05 for average for 2 treatments	.017	.020
Coefficient of variance	7.9%	12.8%

** Reps. 1 and 2 composited, reps. 3 and 4 composited. No statistical analyses.

Soil Description at the Experimental Site

The soil at this experimental site is classed within the Reddish Brown Lateritic Great Soil Group and has been mapped as Olympic silt loam in a soil survey of Clackamas County published in 1926. *Location:* About ½ mile south of Oregon City. SW¼, SW¼, Sec. 5, T3S, R2W.

The plots are located on a 6% north slope in a gently sloping to undulating upland area. The soil is slightly reddish in hue, well drained, permeable, nonstony, and 3 feet plus to the underlying basalt parent rock.

The soil profile has a dark brown, friable, silt loam surface horizon (AP) over a dark brown to brown silty clay loam B horizon that is firm and plastic and has moderate structure. Below 30 inches the solum grades into a nearly structureless, yellowish brown silty clay C horizon that is slightly mottled and has common strongly weathered rock fragments present.