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The Effect of Lime and Phosphorus on the Yield and Phosphorus Content of Legumes in Western Oregon

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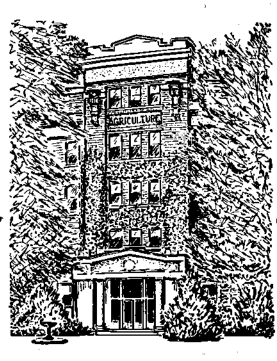

Contents

	Page
Experimental Procedure	4
Discussion of Results	7
Yield of forage from Willamette soil	7
Chemical composition of forage from Willamette soil	10
Forage yields from Olympic soil	11
Chemical composition of forage from Olympic soil	15
Comparisons of chemical composition of forage	17
Summary and Conclusions	17
Literature Cited	18
Appendix	19

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The Effect of Lime and Phosphorus on the Yield and Phosphorus Content of Legumes in Western Oregon

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The yield capacity of different legume species and the ability of these legumes to produce under different soil conditions must be recognized in the establishment of a forage production program.

Alfalfa is consistently the highest yielding legume specie if it is grown on well-drained soils that have been properly limed and fertilized. However, alfalfa stands will not persist under conditions of poor drainage or low fertility.

Birdsfoot trefoil (*Lotus corniculatus L.*), big trefoil (*Lotus uliginosus L.*), and white clover (*Trifolium repens L.*) will survive with more flooding and poorer drainage than most other legumes grown in Oregon. Big trefoil has persisted when submerged for three months. These legumes will generally produce comparatively well on acid soils. Under most Oregon conditions, irrigation is usually required to maintain productive stands of white clovers.

Subterranean clover is a winter annual that is adapted to non-irrigated conditions throughout western Oregon, even though establishment and nodulation are a problem under some conditions. Established stands produce well on soils that are too acid for many other legumes.

Red clover will persist where successful alfalfa stands are difficult to maintain, but it has a narrower range of adaptation than the other legumes discussed previously.

It is difficult to identify the specific reason that yields of legumes are increased following the application of lime to an acid soil. Lime will increase the availability of phosphorus under some conditions. The nitrogen-fixing bacteria that live in symbiotic relationship on the roots of legumes are easier to establish, and may fix nitrogen more efficiently, after acid soils have been limed. Pohlman (*8*) found that for mineral soils it was necessary to have the permanent charge approaching saturation with calcium and magnesium for good nodulation. Precise relationships between soil pH and nitrogen fixation should not be expected. Increasing the pH on acid soils increases the availability of phosphorus and molybdenum. Reduction of excessive amounts of soluble aluminum, manganese, and iron is also recognized as an important factor associated with liming many acid soils (*6*). Thus, changing the soil pH would have different effects on different soils and would depend upon the specific factors associated with a low pH on each soil.

The complex nature of the chemical reactions in acid soils, the varying response of different legume species to lime, and the lack of information under Willamette Valley conditions made it important to evaluate the effect of lime on the production of different legumes grown on the more extensive soil associations in the Willamette Valley. These were the most important reasons for establishing the experiments that will be discussed in this publication.

Experimental Procedure

Six legume species were selected for evaluation in these experiments:

1. Du Puits and Talent alfalfa (*Medicago sativa L.*) on Willamette soil. Du Puits and Vernal alfalfa on Olympic soil.
2. Ladino and New Zealand white clover (*Trifolium repens L.*).
3. Tallarook subterranean clover (*Trifolium subterraneum L.*).
4. Kenland red clover (*Trifolium pratense L.*).
5. Granger birdsfoot trefoil (*Lotus corniculatus L.*).
6. Willamette vetch (*Vicia sativa L.*).

Harvesting problems encountered the first year made it advisable to change from vetch to Dixie crimson clover (*Trifolium incarnatum L.*) for the remainder of the experiment.

Two locations were selected to represent two major soil associations in the Willamette Valley.

The soil on the Hyslop Agronomy Farm, Oregon Agricultural Experiment Station, is mapped as Willamette in published soil surveys (*4*) and was selected to represent the soils on the main valley floor that lie above the present flood plain. This location has imperfect drainage due to a slight fragipan that usually exists from 28 to 30 inches in depth. Alfalfa roots penetrated the fragipan on this location. These soils are typically well supplied with phosphorus and potassium. The pH of surface soils averages about 5.5, with the pH approaching 7.0 at a depth of six to seven feet. Montmorillonite and illite type minerals make up most of the clay minerals in these soils.

The location on the Red Soils Experiment Station has been mapped as Olympic series in published soil surveys (*7*) and was selected as a representative of the residual, reddish brown lateritic soils with basalt parent material that occupy a large percentage of the foothills in the Willamette Valley. These soils are typically quite acid, low in available phosphorus, and often low in potassium. Phosphorus fixation and phosphorus deficiency have been recognized (*3, 10*) as a problem on these soils that are dominated by kaolinitic clays and hydrous oxides (*5*). On this location, established stands of alfalfa utilized moisture to a depth of 30 inches.

The chemical characteristics of the surface soils at the time the experiments were established are given in Table 1.

TABLE 1. CHEMICAL CHARACTERISTICS OF SOILS BEFORE TREATMENT

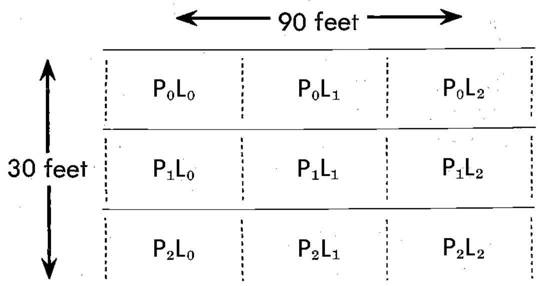
Location	Soil pH	Phos. lb/A	Exchangeable bases in me/100g K	Mg	Ca	Total	Exch. cap. me/100g
Olympic soil	5.4	15.6	.14	2.0	3.1	5.3	15.5
Willamette soil	5.5	60.0	.51	2.3	7.0	9.8	16.0

The samples were analyzed in the Oregon State University Soil Testing Laboratory (*1*). Phosphorus was extracted with Olsen's sodium bicarbonate procedure, and exchangeable bases were extracted with a 10:1 :: solution : soil ratio using ammonium acetate buffered at pH 7.0. Profile descriptions and clay mineral analyses are given in the appendix section.

These experiments were designed as split-plot experiments, with subunits in strips, and were replicated four times. Legumes were planted as main plots to facilitate harvesting. The lime was applied in blocks 30 feet by 30 feet on the Olympic soil and 20 feet by 45 feet on the Willamette soil. The lime treatments were disced thoroughly into the surface five-to-six inches of soil before planting; rates of two and four, or three and six, tons were added on the Willamette and Olympic soils, respectively. The phosphorus was applied in a strip across all three lime rates. The rates of phosphate added were 60 and 120 pounds of phosphate (P_2O_5) (26 and 52 pounds of phosphorus per acre)[1] per acre on the Olympic soil and 60 pounds of phosphate (P_2O_5) per acre on the Willamette soil. Figure 1 shows a plot layout from the Olympic soil.

Blanket applications of 40 pounds of sulfur per acre and 2 pounds of boron per acre as borated gypsum were applied on both locations each year. Ninety pounds of potash (K_2O) per acre were applied the first year, and 150 pounds of potash (K_2O) (75 and 125

[1] Fertilizer guarantees are given as P_2O_5. Multiply P_2O_5 by 0.44 to equal P.



P_1 P_2 = 60, 120 pounds phosphate (P_2O_5) per acre each year; or
= 26, 52 pounds phosphorus (P) per acre.
L_1, L_2 = 3, 6 tons lime per acre applied before seeding.

Figure 1. Plot layout from Olympic soil.

pounds of potassium per acre)[2] thereafter on the Olympic soil. Initial applications of fertilizers were made before seeding; annual applications were made each fall on established stands.

Establishment of legumes on Willamette soil

The alfalfa, red clover, birdsfoot trefoil, and white clover plots were seeded in the spring of 1956. Subterranean clover and vetch were seeded in the fall of 1956. The subterranean clover did not produce a successful stand the first year and was replanted in the fall of 1957. Vetch was eliminated after the 1957 season and crimson clover substituted. The first successful crop of crimson clover was harvested in 1959. The red clover stand was plowed down at the end of the 1958 season, and these plots were reseeded. This procedure allowed four red clover crops in the five-year period.

Establishment of legumes on Olympic soil

Alfalfa, birdsfoot trefoil, red clover, and the two white clovers were seeded in the spring of 1955, while vetch and subterranean clover were seeded in the fall of 1956. Vetch was eliminated after the first year and crimson clover substituted. Crimson clover, red clover, and subterranean clover were killed by winter freezing and heaving the first time they were seeded. Hay yields of red clover and subterranean clover were harvested during 1958, 1959, and 1960; crimson clover was harvested during 1959 and 1960.

Plant analyses

Plant samples were taken from the first cutting in the third year at both locations, and in the fifth year on the Olympic soil location. The top half of the plant was taken on alfalfa, birdsfoot trefoil,

[2] Fertilizer guarantees are given as K_2O. Multiply K_2O by 0.83 to equal K.

red clover, and crimson clover. Saving the top half of the plant avoided soil contamination and leaf loss that can be encountered when whole plant samples are taken. The leaves and petioles of the white clovers and subterranean clover were saved.

The plant samples were dried, ground, and digested in a HNO_3-$HClO_4$ system. Phosphorus was determined colorimetrically by ammonium molybdate—1, 2, 4 aminonaphthol sulfonic acid. Calcium and magnesium were determined, using a versenate titration, on the samples taken from both locations the third year of production.

Statistical analyses of data

Standard analyses of variance were carried out on all yield and chemical analyses data. The differences that were statistically significant will be emphasized in the discussion.

Discussion of Results

Yield of forage from Willamette soil—Hyslop Agronomy Farm

Excellent stands of alfalfa, birdsfoot trefoil, and white clovers were maintained throughout the five years of the experiment. One cutting was harvested from subterranean clover and crimson clover each year. Two cuttings were harvested from the white clovers, red clover, and birdsfoot trefoil, with the second cutting between the first and tenth of July each year. Some regrowth was harvested from the alfalfa following the second cuttings in 1957 and 1958. The third cutting of alfalfa approached the yield of the second cutting in 1959, 1960, and 1961.

There were significant differences in yield between species, as well as a marked difference in the way the different species responded to application of lime. These was no response to phosphorus on this location; thus it is permissible to average across phosphorus rates in the yearly summary of yield data in Table 2 and for the five-year average in Figure 2.

The response of alfalfa to lime is in marked contrast to the slight response to lime from the other species. The 650 pounds per acre response of red clover was the largest yield increase among the clovers or birdsfoot trefoil.

In comparing Granger birdsfoot trefoil and the white clovers, it was apparent that the yield from trefoil was greater, with most of this difference in the second cutting. The larger second-cutting yield of trefoil was accompanied by utilization of stored soil moisture to a greater depth by the deeper root system of the trefoil.

Both alfalfa varieties and birdsfoot trefoil reached their maximum yield in the third crop year. Measurements taken during these

TABLE 2. THE EFFECT OF LIME ON FORAGE YIELD OF DIFFERENT LEGUMES ON WILLAMETTE SOIL, 1957-1961
Yield in Pounds of Oven-Dry Forage Per Acre

Lime treatments[a]	1957	1958	1959	1960	1961	Average
T/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*
			Du Puits alfalfa			
0	6,400	7,290	11,230	12,330	12,210	9,890
2	9,400	9,190	12,960	13,990	13,500	11,810
4	10,840	9,470	13,880	13,890	14,010	12,420
			Talent alfalfa			
0	4,570	6,130	8,550	9,770	9,550	7,720
2	7,440	6,870	11,450	10,850	11,660	9,650
4	8,160	6,760	12,170	11,920	12,080	10,220
			Granger birdsfoot trefoil			
0	5,590	7,560	9,400	8,160	8,980	7,940
2	6,260	8,330	9,340	8,110	8,920	8,200
4	6,140	8,480	9,530	7,850	8,620	8,120
			Tallarook subterranean clover			
0		4,690	5,370	6,270	6,540	5,720
2		4,930	5,400	6,330	7,220	5,970
4		3,700	6,470	7,230	7,440	6,210
			Ladino white clover			
0	5,250	5,770	6,200	4,110	4,720	5,210
2	5,770	5,610	5,780	4,460	4,900	5,300
4	6,160	6,180	5,710	4,670	5,320	5,610
			New Zealand white clover			
0	5,670	6,210	4,990	4,190	4,950	5,200
2	5,580	6,000	5,190	4,800	4,940	5,300
4	5,760	5,780	5,360	4,520	5,200	5,320
			Kenland red clover			
0	6,320	6,750		6,430	5,700	6,300
2	7,920	7,120		6,950	5,390	6,810
4	7,600	7,300		6,950	5,390	6,810
			Dixie crimson clover			
0			5,360	4,880		5,120
2			5,970	5,210		5,590
4			5,610	5,090		5,350

[a] Treatments were averaged for 0 and 60 pounds of phosphate (P_2O_5) per acre. The crimson clover plots receiving lime and phosphorus were lodged so that accurate yield measurements were difficult in 1960.

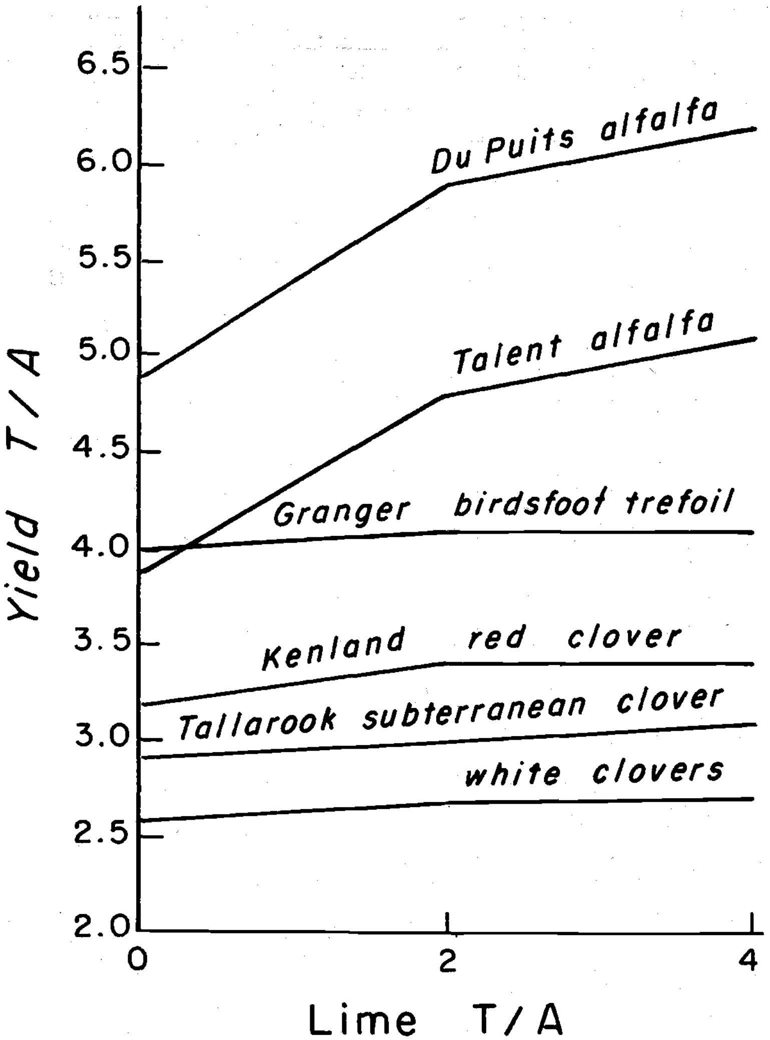


Figure 2. The effect of lime on the yield of legumes, Willamette soil, 1957-1961.

years showed that soil moisture levels on the alfalfa plots approached the wilting point to a depth of eight feet. Utilization of stored soil moisture to this depth enabled alfalfa to produce a third cutting.

Response to lime and the difference between varieties was not significant for New Zealand and Ladino white clovers.

TABLE 3. THE EFFECT OF LIME AND PHOSPHORUS ON THE CHEMICAL COMPOSITION OF DIFFERENT LEGUMES ON WILLAMETTE SOIL, FIRST CUTTING, 1958

Lime treatments	Phosphorus application[a]			
	P_0	P_1	P*	P*
T/A	*% P*	*% P*	*% Ca*	*% Mg*
		Du Puits alfalfa		
0	.37	.35	1.37	.23
2	.35	.41	1.44	.22
4	.39	.38	1.51	.19
		Talent alfalfa		
0	.37	.36	1.42	.16
2	.39	.40	1.60	.19
4	.43	.42	1.78	.15
		Granger birdsfoot trefoil		
0	.40	.37	1.06	.19
2	.42	.39	1.00	.20
4	.42	.39	1.16	.20
		Tallarook subterranean clover		
0	.36	.35	1.36	.21
2	.33	.35	1.58	.20
4	.34	.37	1.59	.18
		Ladino white clover		
0	.42	.43	1.25	.20
2	.39	.39	1.34	.19
4	.46	.40	1.33	.17
		New Zealand white clover		
0	.46	.46	1.28	.20
2	.49	.48	1.36	.19
4	.47	.49	1.33	.20
		Kenland red clover		
0	.28	.30	1.27	.24
2	.29	.27	1.31	.24
4	.26	.28	1.31	.21

[a] P_0 or P_1 = zero or 60 pounds phosphate (P_2O_5) per acre per year.
P* = averaged for zero and 60 pounds phosphate (P_2O_5) per acre per year.

Chemical composition of forage from Willamette soil

The phosphorus content of the forage produced was not affected by the phosphorus or lime treatments. The relatively high levels of phosphorus shown by all legume species (Table 3) was undoubtedly the result of luxury consumption of this nutrient. Critical phosphorus values ranging from .20% to .25% have been suggested for forage legumes by different research workers (*9*). Stage of maturity and the plant part sampled result in some fluctuation of critical values. Phosphorus values ranging from .25% to .47% for all species except red clover indicate luxury consumption of P on plots receiving no phosphorus on this location.

The lime treatments did have a significant effect on the calcium content of the forage produced. However, calcium levels observed on the zero-lime plots were above critical calcium levels that were found by Berger and Pratt (*2*) after reviewing the literature on this subject.

The lime treatments did result in small reductions in the magnesium content of some species. This effect was not consistent and is not considered to be significant.

The absence of a lime x phosphorus interaction and adequate levels of calcium in plants indicate the lime probably had some effect on factors associated with nitrogen fixation for alfalfa. The lack of lime response on the clovers indicates marked species interactions associated with this factor.

Forage yields from Olympic soil—Red Soils Experiment Station

The stands of both New Zealand white clover and Ladino white clover had deteriorated by the spring of 1959. These plots were plowed and reseeded immediately following the harvest in early May. A good stand was obtained and a normal crop produced for both white clovers during 1960.

The red clover plots were plowed following the first harvest in 1959 and reseeded to provide a crop in 1960.

Good stands of birdsfoot trefoil and alfalfa were obtained on all plots the first year. A good stand of birdsfoot trefoil was maintained on all treatments throughout the five years of the experiment, and its yield and vigor on the zero-lime plots improved with age. The stand of alfalfa soon deteriorated on the zero-lime plots; most of the yield recorded on these plots was from broad-leafed weeds and weedy grasses. Good stands were present in 1960 on all Du Puits alfalfa plots that had received lime at the time of seeding. The stand on some of the Vernal alfalfa plots that had received three tons of lime had started to deteriorate by 1960.

Invasion of velvet grass was a problem on all clover plots and on the alfalfa plots that were not limed. Du Puits alfalfa plots that had received lime and a complete fertilizer had very little invasion of velvet grass.

Four different patterns of response from lime and phosphorus were evident on the Olympic soil. These responses are presented in Figure 3 and Tables 4 and 5.

One. Du Puits alfalfa yielded more than Vernal, but the pattern of response was similar. Lime was essential to maintain a successful stand of alfalfa. There was some increase in yield when the rate of

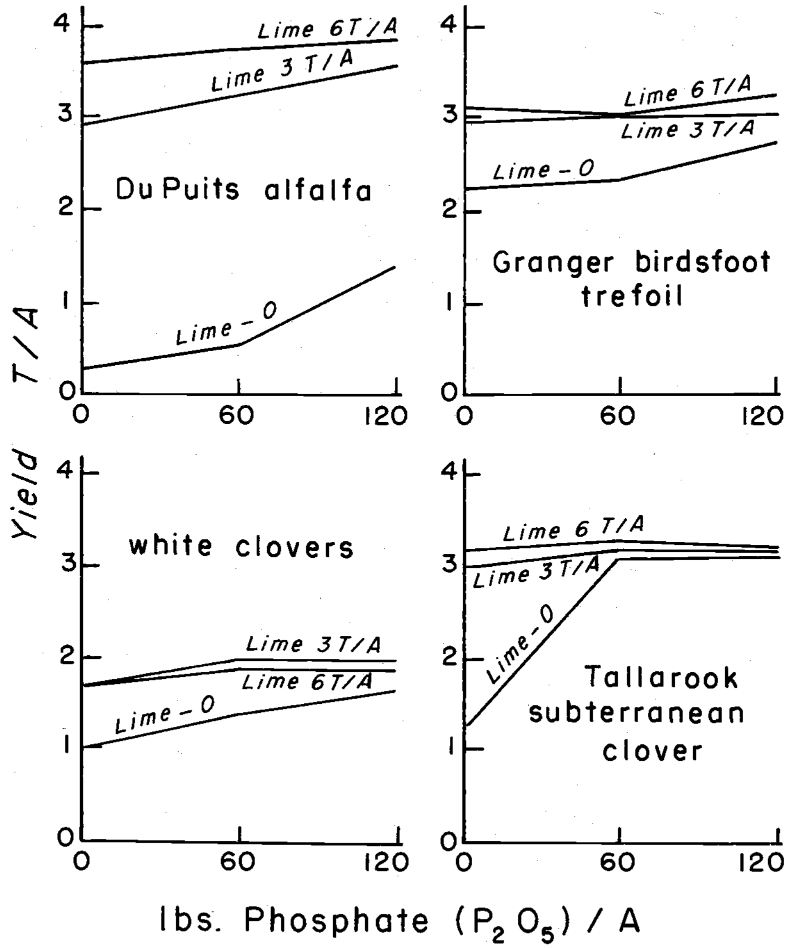


Figure 3. The effect of lime and phosphorus on the yield of legumes, Olympic soil, 1956-1961.

lime was increased from three to six tons. Alfalfa showed very little response from phosphorus; apparently the three-ton rate of lime resulted in a soil environment that enabled the alfalfa plants to obtain phosphorus from the soil. The response of Vernal alfalfa to phosphorus increased on the three-ton-lime plots during the fourth and fifth year, giving evidence of a lime x phosphorus interaction at this level of lime. Also, some Du Puits alfalfa plants were maintained on the high-phosphorus zero-lime plots. The vigor of these plants increased with each annual application of phosphorus. Both alfalfa varieties produced maximum yields in the third year.

TABLE 4. SUMMARY TABLE. THE EFFECT OF LIME AND PHOSPHORUS ON THE FORAGE YIELD OF DIFFERENT LEGUMES ON OLYMPIC SOIL

Pounds of Oven-Dry Forage Per Acre Per Year

Yield of Du Puits alfalfa, 1956-1960 average

P_2O_5 *lb/A*	Tons of lime/A 0	3	6
	lb/A	*lb/A*	*lb/A*
0	590[a]	5,850	7,130
60	1,080	6,350	7,360
120	2,750	7,200	7,690
Avg.	1,470	6,470	7,390

Yield of Vernal alfalfa, 1956-1960 average

P_2O_5 *lb/A*	Tons of lime/A 0	3	6
	lb/A	*lb/A*	*lb/A*
0	570[a]	4,470	6,170
60	750	6,130	6,480
120	1,070	6,340	6,670
Avg.	800	5,650	6,440

Yield of Granger birdsfoot trefoil, 1956-1960 average

P_2O_5 *lb/A*	Tons of lime/A 0	3	6
	lb/A	*lb/A*	*lb/A*
0	4,420[a]	6,030	6,260
60	4,710	5,990	6,000
120	5,300	6,040	6,370
Avg.	4,810	6,020	6,210

Yield of Tallarook subterranean clover, 1956-1960 average

P_2O_5 *lb/A*	Tons of lime/A 0	3	6
	lb/A	*lb/A*	*lb/A*
0	2,400[a]	6,070	6,490
60	6,100	6,490	6,640
120	6,230	6,440	6,480
Avg.	4,910	6,330	6,540

Yield of Ladino white clover, 1956-1960 average

P_2O_5 *lb/A*	Tons of lime/A 0	3	6
	lb/A	*lb/A*	*lb/A*
0	1,990[a]	3,330	3,480
60	2,800	4,080	3,920
120	3,400	3,850	3,740
Avg.	2,730	3,750	3,710

Yield of New Zealand white clover, 1956-1960 average

P_2O_5 *lb/A*	Tons of lime/A 0	3	6
	lb/A	*lb/A*	*lb/A*
0	2,000[a]	3,660	3,440
60	2,910	3,790	3,720
120	3,380	4,140	3,920
Avg.	2,760	3,860	3,690

Yield of Kenland red clover, 1956-1960 average

P_2O_5 *lb/A*	Tons of lime/A 0	3	6
	lb/A	*lb/A*	*lb/A*
0	1,290[a]	4,380	4,360
60	3,460	5,140	5,060
120	4,220	5,280	5,020
Avg.	2,990	4,930	4,820

Yield of Dixie crimson clover, 1956-1960 average

P_2O_5 *lb/A*	Tons of lime/A 0	3	6
	lb/A	*lb/A*	*lb/A*
0	2,820[a]	4,050	4,240
60	3,880	4,160	4,940
120	4,150	5,200	5,270
Avg.	3,610	4,470	4,820

[a] Yield in pounds per acre of oven-dry forage.

TABLE 5. THE EFFECT OF LIME ON YIELD OF DIFFERENT LEGUMES ON OLYMPIC SOIL, 1956-1960
Yield in Pounds of Oven-Dry Forage Per Acre

Lime treatments[a]	1956	1957	1958	1959	1960	Average
T/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*
			Du Puits alfalfa			
0	2,060	140	2,440	940	1,790	1,470
3	3,610	5,940	7,640	7,170	7,960	6,460
6	4,220	7,280	8,350	8,470	8,650	7,390
			Vernal alfalfa			
0	2,140	110	1,460	50	230	800
3	3,390	4,570	7,010	5,680	7,600	5,650
6	3,320	5,620	7,800	7,280	8,190	6,440
			Granger birdsfoot trefoil			
0	1,520	3,740	5,600	6,330	6,870	4,810
3	3,240	5,970	7,250	7,000	6,650	6,020
6	3,160	6,220	7,940	6,910	6,820	6,210
			Tallarook subterranean clover			
0			4,420	5,290	5,020	4,910
3			6,190	6,310	6,500	6,330
6			6,350	6,450	6,810	6,540
			Ladino white clover			
0	1,590	3,470	4,910	430	3,250	2,730
3	2,780	4,220	6,850	1,130	3,810	3,760
6	3,050	4,460	6,500	770	3,780	3,710
			New Zealand white clover			
0	2,010	2,990	4,440	1,230	3,160	2,770
3	3,240	4,010	6,800	1,720	3,470	3,850
6	2,830	4,310	6,280	1,620	3,420	3,690
			Kenland red clover			
0			5,210	2,220	1,530	2,990
3			7,870	3,950	2,980	4,930
6			7,960	3,600	2,890	4,820
			Dixie crimson clover			
0				5,470	1,760	3,610
3				6,210	2,720	4,470
6				6,170	3,460	4,820

[a] Treatments were averaged for 0, 60, 120 pounds phosphate (P_2O_5) per acre.

Two. Birdsfoot trefoil showed a response from both phosphorus and lime during the first two years of hay production. There was a lime x phosphorus interaction evident, since the response from phosphorus was present only on the zero-lime plots. It is important to note that the yield of birdsfoot trefoil on the zero-lime zero-phosphorus plots increased each year until the fifth year, when this treatment produced 91% of the maximum birdsfoot trefoil yield.

Three. Subterranean clover showed a marked lime x phosphorus interaction, with six-thousand-pound yields produced from application of either phosphorus or lime. The small difference between the three- and six-ton rate of lime was not significant. The maximum yields were produced from either a combination of lime and phosphorus or the six-ton rate of lime.

The response of red and crimson clover to lime and phosphorus was very similar to that of subterranean clover.

Four. The two white clovers showed a very similar response. A significant lime x phosphorus interaction was evident throughout each year of the experiment. Maximum yield was maintained with the three-ton rate of lime and sixty pounds of phosphate (P_2O_5) per acre each year. The white clovers yielded less than other legume species evaluated.

Chemical composition of forage from Olympic soil

The effect of the lime and phosphorus treatments on the phosphorus, calcium, and magnesium content of forage produced is presented in Table 6.

The application of phosphorus consistently increased the phosphorus content of all legumes being tested in 1958 and again in 1960. Since lime increased the yields, it increased the total amount of phosphorus removed by each legume. Also, there was some tendency for lime to increase the phosphorus content of the legumes in the absence of phosphorus fertilization. This was especially evident during 1958 for the white clovers, red clover, and birdsfoot trefoil.

These data would indicate that .25% phosphorus is probably an adequate level of phosphorus for the clovers tested. The critical phosphorus value is apparently higher for birdsfoot trefoil than for the other legumes. The 1958 data showed a response from phosphorus fertilization when forage from the birdsfoot trefoil check plot had .29% phosphorus.

It should be considered that different plant parts were sampled for these different legumes and that all plants were not at the same stage of maturity when they were sampled on the same day. This could contribute to some of the difference in phosphorus contents for the different legumes.

The lime treatment consistently increased the calcium content of the forage produced. The minimum calcium levels on this location, as well as on the Willamette soil, were well above critical levels that have been suggested for legumes (*2*).

TABLE 6. THE EFFECT OF LIME AND PHOSPHORUS ON THE CHEMICAL COMPOSITION OF DIFFERENT LEGUMES ON OLYMPIC SOIL, FIRST CUTTING, 1958 AND 1960

Lime treatments	Phosphorus application[a] 1958 P*	P*	P_0	P_1	P_2	1960 P_0	P_1	P_2
T/A	*% Ca*	*% Mg*	*% P*	*% P*	*% P*	*% P*	*% P*	*% P*
			Du Puits alfalfa					
0	1.45	.25	....	....	....	.23	.26	.32
3	1.75	.22	.26	.29	.35	.24	.29	.29
6	2.08	.26	.28	.33	.32	.25	.27	.30
Avg.			.27	.31	.34			
			Vernal alfalfa					
0	....	....	....	....	....	....	.29	.36
3	1.86	.22	.26	.31	.32	.25	.30	.32
6	2.09	.21	.28	.32	.34	.25	.32	.35
Avg.			.27	.32	.33			
			Granger birdsfoot trefoil					
0	1.07	.34	.29	.34	.32	.25	.34	.35
3	1.18	.28	.32	.35	.34	.27	.36	.36
6	1.45	.28	.32	.33	.33	.27	.36	.39
Avg.			.31	.34	.33			
			Tallarook subterranean clover					
0	1.35	.24	.21	.24	.27	.13	.27	.29
3	1.62	.20	.22	.26	.27	.22	.28	.31
6	1.79	.22	.21	.24	.27	.17	.27	.30
Avg.			.21	.25	.27			
			Ladino white clover					
0	1.57	.22	.19	.24	.30	.25	.29	.32
3	1.62	.23	.25	.27	.27	.25	.34	.36
6	1.77	.23	.22	.27	.26	.28	.32	.38
Avg.			.22	.26	.28			
			New Zealand white clover					
0	1.38	.24	.21	.28	.31	.26	.28	.25
3	1.42	.22	.25	.32	.32	.34	.36	.37
6	1.50	.21	.23	.31	.34	.35	.41	.42
Avg.			.23	.30	.32			
			Kenland red clover					
0	1.46	.30	.21	.21	.25	.26	.27	.29
3	1.78	.26	.22	.25	.26	.25	.26	.29
6	1.97	.25	.25	.27	.28	.24	.26	.27
Avg.			.23	.24	.26			
			Dixie crimson clover					
0						.28	.28	.28
3						.28	.28	.29
6						.27	.30	.30

[a] P* = Average of 0, 60, 120 pounds phosphate (P_2O_5) per acre per year. P_0, P_1, P_2 = 0, 60, 120 pounds phosphate (P_2O_5) per acre each year.

The lime treatments either had no effect on magnesium contents or resulted in slight reductions in magnesium.

Comparisons of chemical composition of forage between locations and legumes

In comparing the chemical composition of the forage produced at the two locations, the phosphorus contents were much higher on the Willamette soil. This would have been predicted from the initial soil test values and lack of phosphorus response. Both the calcium and magnesium values were lower on the Willamette soil than on the Olympic soil.

The consistently low calcium levels and high phosphorus levels for birdsfoot trefoil should be noted. The maximum calcium level reached on birdsfoot trefoil was 1.16% and 1.45% for the Willamette and Olympic soils, respectively. The calcium levels for the zero-lime treatments were 1.06% and 1.07% for the two locations. The calcium levels resulting from the heavier rates of lime applied, as well as the calcium levels for the zero rates of lime, were below those of the other legumes tested.

Summary and Conclusions

The effect of lime and phosphorus on forage production and phosphorous content of six different legume species was evaluated on two of the major soil series in the Willamette Valley. Alfalfa, birdsfoot trefoil, white clover, red clover, crimson clover, and subterranean clover were the legumes evaluated on Willamette and Olympic soil series.

Alfalfa was the highest yielding species on both locations, followed by birdsfoot trefoil, red clover, subterranean clover, crimson clover, and white clover on Willamette soil, and by subterranean clover, birdsfoot trefoil, red clover, crimson clover, and white clover on Olympic soil. Alfalfa was the only legume to show a marked response to lime on the Willamette soil. There was no response to phosphorus on Willamette soil.

There were four different patterns of lime x phosphorus interactions on Olympic soil. These are illustrated in Figure 3.

Application of lime was essential for the production of alfalfa on Olympic soil; there was little response from phosphorus on alfalfa.

On Olympic soil, birdsfoot trefoil showed response from both lime and phosphorus the first year with the response from both becoming smaller as the stand aged. The yield from the plots without lime or phosphorus increased with the age of the planting.

Subterranean clover showed a marked lime x phosphorus interaction on Olympic soil. Six-thousand-pound yields were produced from application of either phosphorus or lime. Maximum yields were produced with a combination of lime and phosphorus or the six-ton rate of lime.

A significant lime x phosphorus interaction was evident each year with white clovers on Olympic soil. Maximum yield was maintained with the three-ton rate of lime plus 60 pounds of phosphate (P_2O_5) per acre each year. The white clovers yielded less than other legume species evaluated.

There were wide differences in response from lime on the two soils evaluated, with small differences in soil pH (see Table 2). Developing a satisfactory basis for predicting response from lime will require an evaluation of the different factors affecting the availability of nutrients on acid soils for each group of acid soils that have differences in colloidal materials contributing to the exchange capacity of the soil.

The phosphorus contents of forage from the Willamette soil and the calcium contents of forage from both locations were well above critical levels suggested for these nutrients. The calcium contents of the forage were higher from the Olympic soil while the phosphorus contents were higher from the Willamette soil. Application of phosphorus consistently increased phosphorus contents of forages produced on the Olympic soil.

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Appendix

Soil Descriptions at the Experimental Sites

Olympic soil

The soil at this experiment 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 one-half 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 three 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.

Willamette soil

The soil at this experimental site is in either the Gray-Brown Podzolic or Prairie (Brumizen) great soil group and has been mapped as Willamette silt loam in a soil survey of Benton County published in 1924. Location: Hyslop Farm—SW¼, NE¼, Sec. 8, T11S, R4W.

The plots are located on a level terrace surface with a slope generally less than 1%. The soil is moderately well drained, nonstony, and is developed from water-deposited silty material.

The soil profile has a very dark, grayish brown, friable, silt loam surface over a dark, yellowish brown, silty clay loam B horizon with subangular blocky structure. The B horizon grades into a dark brown, silty clay loam C horizon that is permeable to alfalfa roots to a depth of at least eight feet.

APPENDIX TABLE 1. THE EFFECT OF LIME AND PHOSPHORUS ON THE FORAGE YIELD OF LEGUMES, WILLAMETTE SOIL, 1957-1961
Yield in Pounds of Oven-Dry Forage Per Acre

Treatment[a]	1957	1958	1959	1960	1961	Total	Average
	lb/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*
			Du Puits alfalfa				
L_0P_0	6,700	7,070	11,360	12,340	12,400	49,870	9,970
P_1	6,090	7,500	11,090	12,310	12,010	49,000	9,800
Avg.	6,400	7,290	11,230	12,330	12,210		9,890
L_1P_0	9,300	8,750	12,830	13,560	12,900	57,340	11,470
P_1	9,490	9,630	12,080	14,420	14,100	60,720	12,140
Avg.	9,400	9,190	12,960	13,990	13,500		11,810
L_2P_0	11,080	9,120	13,950	12,820	14,290	61,260	12,250
P_1	10,590	9,810	13,810	14,960	13,730	62,900	12,580
Avg.	10,840	9,470	13,880	13,890	14,010		12,420
			Talent alfalfa				
L_0P_0	4,580	5,860	8,900	9,490	9,160	37,990	7,600
P_1	4,550	6,400	8,200	10,050	9,930	39,130	7,830
Avg.	4,570	6,130	8,550	9,770	9,550		7,720
L_1P_0	7,640	7,170	10,750	10,300	11,120	46,980	9,400
P_1	7,230	6,560	12,140	11,390	12,190	49,510	9,900
Avg.	7,440	6,870	11,450	10,850	11,660		9,650
L_2P_0	8,310	7,150	11,770	11,960	11,660	50,850	10,170
P_1	8,000	6,370	12,560	11,870	12,500	15,300	10,260
Avg.	8,160	6,760	12,170	11,920	12,080		10,220
			Granger birdsfoot trefoil				
L_0P_0	5,600	8,030	9,290	8,010	9,060	39,990	8,000
P_1	5,570	7,090	9,510	8,300	8,890	39,360	7,870
Avg.	5,590	7,560	9,400	8,160	8,980		7,940
L_1P_0	6,340	8,270	9,520	7,860	8,610	40,600	8,120
P_1	6,220	8,390	9,150	8,360	9,230	41,350	8,270
Avg.	6,280	8,330	9,340	8,110	8,920		8,200
L_2P_0	6,020	8,410	9,760	7,230	8,440	39,860	7,970
P_1	6,250	8,540	9,290	8,470	8,790	41,340	8,270
Avg.	6,140	8,480	9,530	7,850	8,620		8,120
			Tallarook subterranean clover				
L_0P_0		4,900	5,700	5,740	6,290	22,630	5,660
P_1		4,480	5,040	6,790	6,790	23,100	5,780
Avg.		4,690	5,370	6,270	6,540		5,720
L_1P_0		5,350	5,430	6,500	7,130	24,410	6,100
P_1		4,510	5,360	6,150	7,300	23,320	5,830
Avg.		4,930	5,400	6,330	7,220		5,970
L_2P_0		3,430	6,380	7,070	7,140	24,020	6,010
P_1		3,970	6,550	7,390	7,730	25,640	6,410
Avg.		3,700	6,470	7,230	7,440		6,210

Appendix Table 1. Continued.

Treatment[a]	1957	1958	1959	1960	1961	Total	Average
	lb/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*
			Ladino white clover				
L_0P_0	5,200	5,730	5,500	4,100	4,330	24,910	4,980
P_1	5,290	5,800	6,840	4,120	5,110	27,160	5,430
Avg.	5,250	5,770	6,200	4,110	4,720		5,210
L_1P_0	5,980	5,460	5,990	4,720	4,850	27,000	5,400
P_1	5,550	5,750	5,570	4,200	4,940	26,010	5,200
Avg.	5,770	5,610	5,780	4,460	4,900		5,300
L_2P_0	6,250	5,670	5,510	4,810	5,490	27,730	5,550
P_1	6,070	6,690	5,910	4,520	5,140	28,330	5,670
Avg.	6,160	6,180	5,710	4,670	5,320		5,610
			New Zealand white clover				
L_0P_0	5,630	6,590	4,790	4,030	4,720	25,760	5,150
P_1	5,700	5,820	5,180	4,350	5,170	26,220	5,240
Avg.	5,670	6,210	4,990	4,190	4,950		5,200
L_1P_0	5,070	6,140	5,110	4,570	5,020	25,910	5,180
P_1	6,090	5,850	5,270	5,020	4,850	27,080	5,420
Avg.	5,580	6,000	5,190	4,800	4,940		5,300
L_2P_0	5,380	6,280	5,010	4,450	5,240	26,360	5,270
P_1	6,140	5,270	5,700	4,590	5,150	26,850	5,370
Avg.	5,760	5,780	5,360	4,520	5,200		5,320
			Kenland red clover				
L_0P_0	6,450	6,340		6,270	5,700	24,760	6,190
P_1	6,180	7,160		6,580	5,700	25,620	6,410
Avg.	6,320	6,750		6,430	5,700		6,300
L_1P_0	7,920	6,690		6,400	5,940	26,950	6,740
P_1	7,910	7,550		6,300	6,940	28,700	7,180
Avg.	7,920	7,120		6,350	6,440		6,960
L_2P_0	7,780	6,630		7,130	5,400[b]	26,940	6,740
P_1	7.420	7,970		6,760	5,370[b]	27,520	6,880
Avg.	7,600	7,300		6,950	5,390		6,810
			Dixie crimson clover				
L_0P_0			5,630	4,980		10,610	5,310
P_1			5,090	4,770		9,860	4,930
Avg.			5,360	4,880			5,120
L_1P_0			6,700	5,970		12,670	6,340
P_1			5,230	4,450[b]		9,680	4,840
Avg.			5,970	5,210			5,590
L_2P_0			5,800	5,810		11,610	5,810
P_1			5,420	4,360[b]		9,780	4,890
Avg.			5,610	5,090			5,350

[a] L_1, L_2 = 2 or 4 tons of lime per acre applied in 1955. P_1 = 60 pounds phosphate (P_2O_5) per acre applied each October and before seeding.
[b] Plots were lodged; harvest was difficult.

APPENDIX TABLE 2. THE EFFECT OF LIME AND PHOSPHORUS ON THE FORAGE YIELD OF LEGUMES, OLYMPIC SOIL, 1956-1960
Yield in Pounds of Oven-Dry Forage Per Acre

Treatment[a]	1956	1957	1958	1959	1960	Total	Average
	lb/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*
			Du Puits alfalfa				
L_0P_0	1,830	40	980	....	110	2,960	590
P_1	1,840	70	2,260	470	760	5,400	1,080
P_2	2,520	310	4,070	2,340	4,500	13,740	2,750
Avg.	2,060	140	2,440	940	1,790		1,470
L_1P_0	3,010	5,540	6,850	6,540	7,300	29,240	5,850
P_1	3,750	5,870	7,600	6,670	7,840	31,730	6,350
P_2	4,070	6,410	8,470	8,310	8,730	35,990	7,200
Avg.	3,610	5,940	7,640	7,170	7,960		6,460
L_2P_0	3,900	7,280	7,890	8,130	8,440	35,640	7,130
P_1	4,380	7,260	8,310	8,450	8,400	36,800	7,360
P_2	4,370	7,300	8,840	8,810	9,110	38,430	7,690
Avg.	4,220	7,280	8,350	8,470	8,650		7,390
			Vernal alfalfa				
L_0P_0	1,950	80	600	....	240	2,870	570
P_1	1,940	110	1,710	....	....	3,760	750
P_2	2,520	150	2,080	150	460	5,360	1,070
Avg.	2,140	110	1,460	50	230		800
L_1P_0	3,030	3,010	6,440	4,170	5,700	22,350	4,470
P_1	3,700	5,260	7,100	6,270	8,300	30,660	6,130
P_2	3,440	5,440	7,480	6,600	8,760	31,720	6,340
Avg.	3,390	4,570	7,010	5,680	7,600		5,650
L_2P_0	3,240	6,210	7,360	6,790	7,230	30,830	6,170
P_1	3,010	5,330	7,700	7,780	8,600	32,420	6,484
P_2	3,710	5,330	8,330	7,260	8,730	33,360	6,670
Avg.	3,320	5,620	7,800	7,280	8,190		6,440
			Granger birdsfoot trefoil				
L_0P_0	1,300	3,220	5,060	5,890	6,620	22,090	4,418
P_1	1,320	3,520	5,550	6,450	6,730	23,570	4,714
P_2	1,940	4,480	6,190	6,660	7,250	26,520	5,304
Avg.	1,520	3,740	5,600	6,330	6,870		4,810
L_1P_0	3,490	5,950	7,380	6,800	6,510	30,130	6,026
P_1	3,230	5,810	6,910	7,090	6,920	29,960	5,992
P_2	3,000	6,140	7,460	7,110	6,510	30,220	6,044
Avg.	3,240	5,970	7,250	7,000	6,650		6,020
L_2P_0	3,510	6,340	7,610	6,700	7,140	31,300	6,260
P_1	2,340	5,950	8,370	6,900	6,440	30,000	6,000
P_2	3,620	6,360	7,840	7,140	6,880	31,830	6,366
Avg.	3,160	6,220	7,940	6,910	6,820		6,210

APPENDIX TABLE 2. Continued.

Treatment[a]	1956	1957	1958	1959	1960	Total	Average
	lb/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*
Kenland red clover							
L_0P_0			2,550	820	490	3,860	1,290
P_1			5,890	2,810	1,670	10,370	3,460
P_2			7,200	3,040	2,420	12,660	4,220
Avg.			5,210	2,220	1,530		2,990
L_1P_0			7,610	3,460	2,060	13,130	4,380
P_1			7,710	4,410	3,300	15,420	5,140
P_2			8,290	3,980	3,570	15,840	5,280
Avg.			7,870	3,950	2,980		4,930
L_2P_0			7,830	2,910	2,350	13,090	4,360
P_1			7,980	4,180	3,020	15,180	5,060
P_2			8,060	3,720	3,290	15,070	5,020
Avg.			7,960	3,600	2,890		4,820
Dixie crimson clover							
L_0P_0				4,800	850	5,650	2,820
P_1				6,020	1,740	7,760	3,880
P_2				5,600	2,690	8,290	4,150
Avg.				5,470	1,760		3,610
L_1P_0				6,180	1,910	8,090	4,050
P_1				5,930	2,390	8,320	4,160
P_2				6,530	3,870	10,400	5,200
Avg.				6,210	2,720		4,470
L_2P_0				5,400	3,070	8,470	4,240
P_1				6,300	3,570	9,870	4,940
P_2				6,810	3,730	10,540	5,270
Avg.				6,170	3,460		4,820
Tallarook subterranean clover							
L_0P_0			1,560	3,350	2,290	7,200	2,400
P_1			5,190	6,330	6,790	18,321	6,100
P_2			6,510	6,200	5,990	18,700	6,233
Avg.			4,420	5,290	5,020		4,910
L_1P_0			5,880	6,180	6,140	18,200	6,067
P_1			5,840	6,910	6,730	19,480	6,493
P_2			6,860	5,840	6,620	19,320	6,440
Avg.			6,190	6,310	6,500		6,330
L_2P_0			6,530	6,110	6,820	19,460	6,490
P_1			6,230	6,620	7,080	19,930	6,640
P_2			6,290	6,620	5,630	19,440	6,480
Avg.			6,350	6,450	6,810		6,540

APPENDIX TABLE 2. Continued.

Treatment[a]	1956	1957	1958	1959	1960	Total	Average
	lb/A	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*
			Ladino white clover				
L_0P_0	1,080	2,570	3,300	300	2,680	9,930	1,990
P_1	1,990	3,450	5,130	240	3,180	13,990	2,800
P_2	1,590	3,470	4,910	740	3,250	13,960	2,730
Avg.	1,590	3,470	4,910	430	3,250		2,730
L_1P_0	2,170	4,420	5,910	880	3,290	16,670	3,330
P_1	3,500	4,240	7,560	1,300	3,820	20,420	4,080
P_2	2,680	4,000	7,080	1,200	4,310	19,270	3,850
Avg.	2,780	4,220	6,850	1,130	3,810		3,760
L_2P_0	3,010	4,280	6,010	780	3,300	17,380	3,480
P_1	3,030	4,630	7,240	740	3,950	19,590	3,920
P_2	3,110	4,460	6,250	790	4,090	18,700	3,740
Avg.	3,050	4,460	6,500	770	3,780		3,710
			New Zealand white clover				
L_0P_0	1,830	2,210	3,410	750	1,820	10,020	2,000
P_1	2,000	2,740	4,620	1,340	3,830	14,530	2,910
P_2	2,190	4,010	5,280	1,610	3,820	16,910	3,380
Avg.	2,010	2,990	4,440	1,230	3,160		2,770
L_1P_0	3,480	3,680	6,320	1,860	2,980	18,320	3,660
P_1	3,080	3,560	6,710	1,680	3,930	18,960	3,790
P_2	3,160	4,790	7,360	1,910	3,500	20,720	4,140
Avg.	3,240	4,010	6,800	1,720	3,470		3,850
L_2P_0	2,680	3,790	6,090	1,620	3,010	17,190	3,400
P_1	2,780	4,330	6,340	1,720	3,420	18,590	3,720
P_2	3,030	4,820	6,390	1,530	3,820	19,590	3,920
Avg.	2,830	4,310	6,280	1,620	3,420		3,690

[a] L_1L_2 = 3 or 6 tons of lime per acre applied in 1955. P_1P_2 = 60 or 120 pounds of phosphate (P_2O_5) per acre applied each October and before seeding.