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Effect of Fertilizers on Irrigated Grass-Legume Pastures On an Astoria Soil Series

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Contents

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Effect of Fertilizers on Irrigated Grass-Legume Pastures on an Astoria Soil Series

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Introduction

Production of forage for livestock consumption is the major contribution to agricultural income of the coastal area of Oregon. The cool summer weather and the late spring rain severely limit the production of cash crops that might be grown in this area. Small acreages of grass seed, cranberries, holly, lilies, and other bulbs are the only important exceptions to forage production. The important contribution of forage crops to the economy of this area makes it essential to understand all factors affecting production of these crops.

Reports of planning committees from the coastal counties of Oregon have shown that proper fertilization of grass-legume pastures and maintenance of legumes in the stand of improved pastures is considered to be one of the main pasture and forage production problems in this area. These reports were evaluated before a series of experiments was started in 1956.

The experiments were designed to measure the effect of lime and fertilizer on production and the changes in botanical composition of New Zealand white clover and orchardgrass pastures on the Astoria soil series,[1] one of the more important upland soils in the area.

It was decided to place major emphasis on factors affecting the production and maintenance of New Zealand white clover in irrigated grass-clover pastures.

Review of Literature

Previous work at the John Jacob Astor Experiment Station indicated response from lime, P,[2] and K[2] when applied for the production of grass-clover pastures. In 1955 soil samples were submitted to the Oregon State University Soil Testing Laboratory from farms in

[1] See appendix for description of Astoria soil series.

[2] Nitrogen, phosphorus, potassium, and magnesium will be referred to as N, P, K, and Mg throughout this paper. P x 2.29 = P_2O_5 and K x 1.2 = K_2O.

the coastal area. Analysis of the soil showed 65% with a pH below 5.5; 85% with P values below 20 pounds per acre, which would place the soils in the category where response from P fertilizers would be expected; and 66% with K values below 400 pounds per acre, which would indicate the probability of a response from K fertilizers.

Experiments on irrigated pastures on Vancouver Island *(6)* have shown responses from K, and experiments at the Western Washington Experiment Stations at Puyallup and Mt. Vernon *(2, 5)* have shown response from P and K. Response of forage grasses to applications of N fertilizer has been widely recognized for a number of years in this area, but the use of N fertilizer on grass-legume pastures presents many problems. Most research workers *(2, 3, 4, 5, 6, 8, 9, 10)* believe that the use of N increases the yield of grass and reduces the percentage of legume in the mixture. In some cases there is, in effect, a trading of fertilizer N for legume N, with the total pounds of protein produced remaining fairly constant. This is illustrated in the work of Gardner *et al.* on Vancouver Island *(6)*.

The history of response from P and K on soils throughout the area west of the Cascades, the low soil pH on the experimental area, and the summaries of soil test values from farm samples were considered in deciding to place major emphasis in the experiments on the response from lime, P, and K.

Experimental Procedure

A series of experiments was started on the John Jacob Astor Experiment Station at Astoria, Oregon, in 1956 to evaluate the effects of lime and fertilizer treatments on the production and maintenance of clover in the stand of grass-legume pastures grown on the Astoria soil series.

Each experimental area was sprayed with 15 pounds of dalapon per acre to kill bentgrass. A period of clean cultivation before planting, starting three to four weeks after application of dalapon, insured minimum competition from undesirable species during stand establishment. The treatments on all experiments were replicated a minimum of three times with individual plots 8 feet wide and 33 feet long. Lime treatments were broadcast with an 8-foot fertilizer spreader, and the entire plot area was roto-tilled twice to insure maximum mixing of lime with the soil prior to seeding. Ground limestone with 98% calcium carbonate, 95% passing a 60-mesh sieve, was used as a source of lime. Treble superphosphate, muriate of potash, and magnesium sulfate were used to supply P, K, and Mg. These treatments were broadcast over individual plots prior to seeding. The P, K, and Mg were reapplied each spring following establishment of the experiment. One-half of the K was applied on the first application and the other half was applied between June 15 and 30, except where time of application of K was being evaluated.

A mixture of three pounds of New Zealand white clover and eight pounds of S143 orchardgrass was seeded over the experimental area following application of the lime and fertilizer treatments. Previous research had shown these two species were compatible and among those best adapted to local conditions. The area was rolled and then irrigated with a sprinkler irrigation system to achieve optimum stand establishment.

A minimum of 2 feet was always trimmed from both ends of each plot before harvesting to minimize border effect. The plots were harvested with a forage-plot harvester described by Jackson and Page (*7*). The crops were harvested at an immature stage of growth, with four to six weeks between cuttings to simulate grazing conditions. The green weight of the total area harvested was recorded, and moisture samples were taken from each plot to measure the percent moisture for converting plot green weights to pounds of dry matter produced per acre. All yield and chemical analysis data were analyzed statistically. Only the yield differences that are statistically significant will be discussed.

Soil samples were taken at the beginning and termination of experiments to evaluate the effects of lime and fertilizer treatments on changes in soil test values during the period of the experiment and to relate the response from application of fertilizers to the original soil test values existing on the experimental area. Samples were analyzed by the Oregon State University Soil Testing Laboratory, using the procedures outlined by Alban and Kellog (*1*).

Selected forage samples were taken during the experiments to evaluate the effect of the fertilizer and lime treatments on changes in botanical composition and for chemical analyses. Individual plots were rated at the termination of the experiments to evaluate the invasion of bentgrass and other weedy species in the different fertilizer treatments.

The plot areas were irrigated with sprinkler irrigation systems. Approximately 3 inches of irrigation water were applied uniformly over the plot area whenever the crop showed signs of moisture stress or whenever the soil was judged to be dry enough to limit growth. This generally resulted in irrigations on 15- to 20-day intervals whenever rainfall was not adequate to maintain soil moisture.

Experimental Results

Four different experiments were carried out during the period of investigation. A brief outline of the specific procedure followed in each experiment will be included as the results from each experiment are presented.

Experiment 205

Experiment 205 was started in 1956. An earlier experiment had been established in 1920 to evaluate the effects of repeated applications of lime and manure in combination with low rates of P and K on the production of different crops; 10 tons of manure per acre were applied every four years. Rates of lime application are given in Table 1. The individual plots in the 1920 experiment were 33 feet wide and 66 feet long. This made it possible in 1956 to use each individual plot as a replication for a 2 x 2 x 2 P x K x Mg factorial experiment with four replications. Each of the new plots was 8 feet wide and 33 feet long. The general procedure described for establishing experiments was used for this experiment.

Table 1. Chemical Analyses of Surface Soil Samples From Experiment 205 in 1955[1]

Plot	Treatment before 1955[2]				Soil pH	Soil analysis values[3]				
						P	K	Bases (me/100g)		
								K	Ca	Mg
						lb/A	lb/A			
1	L	–	–	–	6.4	6	130	.17	17.0	2.0
2	L	–	–	M	6.2	11	210	.24	16.8	2.7
3	L	P	–	–	6.1	8	100	.13	13.4	1.5
4	L	P	–	M	6.0	19	160	.20	14.4	2.5
5	L	–	K	–	6.2	6	210	.24	12.5	1.4
6	L	–	K	M	6.1	12	320	.41	15.0	2.4
7	L	P	K	–	5.6	15	170	.22	9.8	2.0
8	L	P	K	M	6.2	27	340	.43	14.3	2.5

[1] Surface soil samples (0-7 inches) were analyzed by OSU Soil Testing Laboratory. Phosphorus was extracted with sodium bicarbonate, and exchangeable bases (K, Ca, Mg) were extracted with 1 N ammonium acetate buffered at pH 7.0 and using a 1:10 soil:solution ratio.

[2] Previous treatments were: L refers to lime applied at 2 tons per acre in 4-year intervals—plots 1 through 4 had received 20 tons of lime per acre, plots 5 through 8 had received 8 tons of lime per acre; P refers to 9 pounds of P per acre applied each year since 1920; K refers to 17 pounds of K per acre applied each year since 1920; and M refers to 10 tons of manure per acre once every 4 years. All tables will use rates of P and K with conversion factors P x 1.29 = P_2O_5, P_2O_5 x .44 = P, and K x 1.2 = K_2O, K_2O x .83 = K.

[3] Plots were sampled before plowing and after a series of surface applications of lime. This probably explains the higher pH, Ca, and Mg values than those found in Table 2, where the soil samples were taken after plowing and reestablishment of the pasture mixture.

Table 1 shows the analyses from surface soil samples for each replication of the modified experiment with the previous fertilizer and manure treatments. Table 2 shows the soil analyses from surface samples from the modified treatments taken at the termination of this experiment. The yield data for 1956 to 1958 in pounds of dry matter produced each year are shown in Table 3.

Response from K. The application of K increased the yield 2,200 and 2,000 pounds per acre on the manured and nonmanured treatments, respectively, for the three-year average. There was also a marked increase in quality of forage, with very little clover and a large amount of weeds in the plots not receiving K. This indicates that application of K is necessary for maximum production of pastures and for the maintenance of clover in stands with soil-test values as high as 340 pounds of K per acre when they are receiving applications of 10 tons of manure once every four years.

Table 2. CHEMICAL ANALYSES OF SURFACE SOIL SAMPLES FROM EXPERIMENT 205 IN 1961[1]

	Previous treatments		Soil analysis values[4]					
						Bases (me/100g)		
Plot	Before 1955[2]	1956 to 1961[3]	Soil pH	P	K	K	Ca	Mg
				lb/A	*lb/A*			
1A	L – – –	P –	6.1	18	140	.18	10.5	1.1
1B		P K	5.9	15	210	.26	8.8	0.8
2A	L – – M	P –	6.0	21	140	.18	8.8	1.1
2B			5.9	22	210	.27	11.4	1.1
3A	L P – –	P –	6.0	17	160	.20	11.4	1.2
3B		P K	5.8	16	210	.27	9.6	0.9
4A	L P – M	P –	6.0	25	170	.22	12.9	1.4
4B		P K	5.9	17	280	.36	11.4	1.4
5A	L – K –	P –	5.9	19	140	.18	10.2	1.0
5B		P K	5.9	21	260	.33	9.4	1.0
6A	L – K M	P –	6.0	29	180	.23	12.3	1.4
6B		P K	5.9	29	270	.34	11.4	1.4
7A	L P K –	P –	6.0	19	160	.20	9.6	1.1
7B		P K	5.8	20	180	.23	9.1	1.1
8A	L P K M	P –	5.9	32	170	.22	10.7	1.5
8B		P K	5.9	24	260	.33	9.6	1.4

[1] See Table 1 for methods of analysis. Surface soil samples (0-7 inches) were analyzed.

[2] L refers to lime, applied at 2 tons per acre in 4-year intervals; plots 1A through 4B received 20 tons, while plots 5A through 8B received 8 tons of lime per acre. P refers to 9 pounds P per acre each year; K refers to 17 pounds K per acre each year; and M refers to manure applied at 10 tons per acre in 4-year intervals.

[3] 1956-1961 P equals 44 pounds P per acre each year; K equals 166 pounds K per acre each year.

[4] Soil analyses of surface soil samples in 1955 are reported in Table 1.

Table 3. Effect of Fertilizer and Manure Treatments on the Yield of Improved Grass-Legume Pastures, Experiment 205

Treatment[1]					Forage yield (dry weight)			
					1956	1957	1958	Avg.
					lb/A	lb/A	lb/A	lb/A
1	–	–	–	–	5,200	5,600	7,230	6,010
2	–	P	–	–	6,380	5,910	6,770	6,350
3	–	–	K	–	6,140	6,540	9,340	7,340
4	–	P	K	–	7,910	7,260	9,930	8,370
5	Mg	–	–	–	6,870	5,400	6,910	6,390
6	Mg	P	–	–	6,660	5,080	6,180	5,970
7	Mg	–	K	–	7,730	6,850	9,360	7,980
8	Mg	P	K	–	8,830	8,510	10,090	9,140
9	–	–	–	M	6,700	5,400	8,070	6,720
10	–	P	–	M	8,160	5,190	7,220	6,860
11	–	–	K	M	8,240	6,740	9,740	8,240
12	–	P	K	M	9,610	8,400	10,350	9,450
13	Mg	–	–	M	6,470	5,810	7,670	6,650
14	Mg	P	–	M	7,430	6,120	7,000	6,850
15	Mg	–	K	M	8,350	7,520	9,990	8,620
16	Mg	P	K	M	10,500	8,300	10,030	9,610

[1] P refers to 44 pounds P per acre applied each year; K refers to 166 pounds K per acre applied each year in split application—half April 1 and half July 1; Mg refers to 30 pounds Mg per acre applied in 1956 and 1957; M refers to 10 tons manure per acre applied in 1957 (manure had been applied in 4-year intervals since 1918).

Figure 1 shows the effect of K fertilizer on maintenance and production of legumes in these plots. The amount of weeds evident in the plot which received no K emphasizes the importance of maintaining legumes in a pasture to maintain the quality of the forage produced.

A change of analyses for surface soil samples from the plots receiving annual applications of K plus previous application of manure (Table 1, Number 8), from 340 pounds of K per acre to 260 pounds of K per acre (Table 2, Number 8B) by November of 1961 indicates that a combination of 166 pounds of K per acre applied each year plus a 10-ton application of manure once each four years will not increase the K soil-test values to high levels. The soil-test values varied from 100 to 340 pounds of K per acre when the experiment was started in 1956 (Table 1). These values changed to 160 to 170 pounds of K per acre (Table 2, Numbers 3A and 8A) where K fertilizer had not been applied and to 210 and 260 pounds of K per acre (Table 2, Numbers 3B and 8B) where K had been applied each year. The plots receiving manure had a 10-ton per acre application in 1957 and again in 1961.

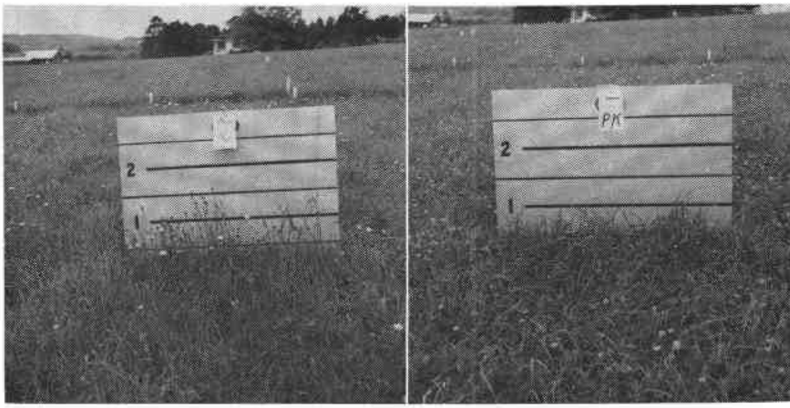

Figure 1. The effect of potassium on maintenance and production of legumes. Note the weedy growth in the plot on the left that received no potassium.

Response from P. The increase in yield from P averaged about 1,000 pounds of dry weight per acre per year over the three-year period where adequate K had been applied (treatments 3 versus 4, or 7 versus 8 in Table 3) and was statistically significant. There were no noticeable effects of the P treatments on the maintenance of clover in the stand or on the prevention of invasion of weedy species. These data would indicate that small responses from application of P would be anticipated on the Astoria soil series with soil-test values ranging from 6 to 27 pounds of P per acre where the soils had a pH of 5.6 or above (Table 1).

Response from Mg. There was no indication of response from application of Mg, so the Mg treatments were discontinued after 1957. Table 2 shows soil analyses of samples taken at the termination of this experiment in 1961. Plowing and cultivation after soil samples were taken in 1955 mixed the surface applications of lime to a greater depth; this probably explains the differences in Ca and Mg analyses found in Tables 1 and 2.

Changes in soil analyses values. The applications of lime that were made before 1955 on this experimental area maintained the pH at about 6.0. Twenty tons of lime were applied at the rate of 2 tons per acre every four years between 1918 and 1955 on plots 3 and 4. A total of 8 tons of lime per acre had been applied on plots 5 and 6, with applications of 2 tons per acre in 1938, 1942, 1946, and 1950.

There was some increase in P soil-test values between 1955 and 1961 on the plots receiving annual applications of P. However, this increase was very small compared to the total amount of P that was applied—seven annual applications of 44 pounds (100 pounds of P_2O_5) per acre.

Plots with lower K soil-test values that did not receive K remained at about the same soil-test value, while plots receiving annual applications of K increased slightly in K. Two of the original plots (Table 1, Numbers 6 and 8) had fairly high K soil-test values. These values were reduced by heavy cropping, even with annual applications of 166 pounds of K per acre and applications of manure every four years. Since K fixation would not be a problem on these soils, this experiment indicates that the 166 pounds of K per acre applied each year approached the requirement of the crop.

Experiment 207

Effects of the treatments on Experiment 205 were evident in the spring of 1956. These were used as the basis for Experiment 207, established in the fall of 1956. This experiment was located on land that had been cleared from stumps and fern in 1946. Grazing with cattle and mowing for grass hay had largely eliminated the fern from the area. Two or three light applications of fertilizer had been applied since the area had been cleared.

Table 4 shows the analyses of soil samples that were present on this location at the time the experiment was established (1956) and at the time the experiment was terminated (1961). Table 5 shows the combination of lime and fertilizer treatments that were established for this experiment. Procedures previously described were followed for elimination of competing weedy species, broadcasting of P and K, application and mixing of lime, seeding the improved pasture species, and sprinkler irrigation.

The yield data for 1957, 1958, and 1959 are presented in Table 5. Optimum soil moisture was maintained with irrigation throughout the 1957 and 1958 growing seasons. Irrigation was not continued in 1959; this limited the production to two cuttings and accounts for the 1959 yields being lower than the 1957 and 1958 yields.

Response from K. Response from application of K was the most outstanding effect of fertilizer in this experiment. There was a marked increase in yield and marked improvement in the stand of clover at the end of three years on the plots receiving application of K.

The increases in yield from K for 1957, 1958, and 1959 are summarized in Table 6. It is important to note that the yield from K continued to increase each year—13% in 1957, 29% in 1958, and 67% in 1959. The decrease in legumes in the plots not receiving K fertilizer, as

Table 4. CHEMICAL ANALYSES OF SOIL SAMPLES FROM EXPERIMENT 207

	Treatment[1]		Soil test values					
						Bases (me/100g)		
			Soil pH	P	K	K	Ca	Mg
				lb/A	lb/A			
0	None	(0-6″)	5.1	12	260	.33	1.3	1.0
1	L_0 P_2 K_2	(0-6″)	5.0	33	290	.37	1.4	0.5
	L_0 P_2 K_2	(6-12″)	5.0	13	270	.35	1.4	0.3
	L_0 P_2 K_2	(12-24″)	5,1		190	.25	0.7	0.4
	L_0 P_2 K_2	(24-36″)	5.4		350	.45	0.8	0.4
2	L_1 P_2 K_2	(0-6″)	5.5	41	420	.54	9.8	1.2
	L_1 P_2 K_2	(6-12″)	5.3	8	240	.31	2.3	0.3
	L_1 P_2 K_2	(12-24″)	5.3		230	.30	1.8	0.3
	L_1 P_2 K_2	(24-36″)	5.3		250	.32	0.8	0.3
3	L_2 P_2 K_2	(0-6″)	5.7	32	670	.86	16.2	2.0
	L_2 P_2 K_2	(6-12″)	5.6	14	270	.35	5.0	0.6
	L_2 P_2 K_2	(12-24″)	5.2		340	.43	1.4	0.5
	L_2 P_2 K_2	(24-36″)	5.3		170	.22	1.1	0.3
4	L_3 P_2 K_2	(0-6″)	6,1	40	440	.56	25.3	1.7
	L_3 P_2 K_2	(6-12″)	5.6	19	240	.31	9.1	0.9
	L_3 P_2 K_2	(12-24″)	5.3		250	.32	2.0	0.4
	L_3 P_2 K_2	(24-36″)	5.2		300	.38	1.3	0.3
5	L_4 P_2 K_2	(0-6″)	6.9	59	430	.55	43.1	2.0
	L_4 P_2 K_2	(6-12″)	6.1	14	250	.32	13.1	0.7
	L_4 P_2 K_2	(12-24″)	5.3		260	.33	2.2	0.3
	L_4 P_2 K_2	(24-36″)	5.5		200	.26	2.0	0.4
6	L_1 P_0 K_0	(0-6″)	5.5	21	160	.21	7.3	1.3
7	L_1 P_0 K_2	(0-6″)		24	270	.34	5.9	1.0
8	L_1 P_1 K_0	(0-6″)		33	160	.20	7.8	1.2
9	L_1 P_1 K_2	(0-6″)		35	320	.41	7.8	1.5
10	L_1 P_2 K_0	(0-6″)		45	180	.23	5.1	1.0
11	L_1 P_2 K_1	(0-6″)		35	190	.24	8.9	1.3
12	L_3 P_0 K_0	(0-6″)	6.1	20	170	.22	19.6	1.2
13	L_3 P_0 K_2	(0-6″)		20	330	.42	19.7	1.1
14	L_3 P_1 K_0	(0-6″)		26	160	.21	17.8	1.4
15	L_3 P_1 K_2	(0-6″)		29	300	.39	19.8	1.4
16	L_3 P_2 K_0	(0-6″)		41	160	.21	19.5	1.4
17	L_3 P_2 K_1	(0-6″)		43	190	.24	21.1	1.3

[1] Sample of check plot taken before treatment in 1956. Samples of treatments 1 through 17 were taken in 1961 at termination of experiment. L_1, L_2, L_3, L_4 refer to 3, 6, 12, 24 tons lime per acre respectively applied in 1956; P_1, P_2 refer to 44, 88 pounds P per acre applied each year after 1956; K_1, K_2 refer to 83, 166 pounds K per acre applied each year after 1956.

Table 5. FORAGE YIELDS, AVERAGE PERCENT LEGUME, AND PERCENT WEEDY GRASSES, EXPERIMENT 207

	Treatments[1]	Forage yield[2] 1957	Forage yield[2] 1958	Forage yield[2] 1959	Clover[3] 1957	Clover[3] 1958	Weedy grasses[4] 1960
		lb/A	lb/A	lb/A	%	%	%
1	L_0 P_2 K_2	9,330	7,830	3,120	60	50	10
2	L_1 P_0 K_0	8,130	7,100	2,210	40	30	40
3	L_1 P_1 K_0	9,000	6,660	1,970	40	10	40
4	L_1 P_2 K_0	8,860	7,030	2,140	40	20	30
5	L_1 P_0 K_2	9,660	8,280	2,940	60	40	20
6	L_1 P_1 K_2	10,830	9,220	3,780	60	50	0
7	L_1 P_2 K_2	9,820	9,020	3,590	60	40	10
8	L_2 P_0 K_0	7,130	6,700	1,860	40	20	40
9	L_2 P_1 K_0	9,400	7,230	2,080	50	20	30
10	L_2 P_2 K_0	9,550	5,950	1,670	30	10	40
11	L_2 P_0 K_2	9,940	9,250	3,310	50	40	10
12	L_2 P_1 K_2	11,210	9,520	3,540	60	40	10
13	L_2 P_2 K_2	11,050	9,800	3,510	60	40	10
14	L_3 P_0 K_0	9,330	6,760	2,180	40	20	40
15	L_3 P_1 K_0	8,640	6,450	2,330	30	10	40
16	L_3 P_2 K_0	9,840	7,360	2,170	40	20	30
17	L_3 P_0 K_2	10,020	9,060	3,170	50	40	10
18	L_3 P_1 K_2	11,270	9,230	3,480	60	30	10
19	L_3 P_2 K_2	11,360	9,520	3,610	50	30	10
20	L_1 P_2 K_1	10,210	8,530	3,320	50	30	10
21	L_2 P_2 K_1	10,330	8,800	2,540	60	30	30
22	L_3 P_2 K_1	11,010	8,310	2,860	50	30	20
23	L_4 P_2 K_2	12,000	9,490	3,450	50	30	10

[1] See footnote 2, Table 4, for description of treatments.

[2] The plots were irrigated only during 1957 and 1958.

[3] Percent clover was a visual rating. Scores based on visual estimates were adjusted on the basis of hand-separated samples.

[4] Percent weedy grasses was a visual rating. Weedy grasses were bentgrass and sweet vernal grass.

shown in Table 6 and Figure 2, was undoubtedly a major factor contributing to the lower yield on these plots. A good stand of legumes was maintained on the unlimed plots that had received application of P and K each year.

At the end of the 1959 season, 166 pounds of K per acre were added in a split application to half of each plot that had not received K. Table 7 summarizes the increase in legumes measured by 1962 on the K-treated half of the plot when compared with the half of the plot that had not received K and with those plots that had received K since 1956.

Table 6. EFFECTS OF POTASSIUM ON YIELD AND PROPORTION OF CLOVER, EXPERIMENT 207

Treatment[1]	Forage[2] Yield 1957			Increase from K 1957			Clover[3] 1957	
	1957	1958	1959	1957	1958	1959	1957	1958
	lb/A	lb/A	lb/A	%	%	%	%	%
1 L_1 P_2 K_0	8,860	7,030	2,140	......	......	......	40	20
2 L_1 P_2 K_1	10,210	8,530	3,320	15.2	21.3	55.1	50	30
3 L_1 P_2 K_2	9,820	9,020	3,590	10.8	28.3	67.8	60	40
4 L_3 P_2 K_0	9,840	7,360	2,170	......	......	......	40	20
5 L_3 P_2 K_1	11,010	8,310	2,860	11.9	12.9	31.8	50	30
6 L_3 P_2 K_2	11,360	9,520	3,610	15.4	29.3	66.4	50	40

[1] See footnote 2, Table 4, for description of treatments.

[2] Optimum soil moisture was maintained by sprinkler irrigation in 1957 and 1958. Plots were not irrigated in 1959.

[3] Percent clover determined by visual estimates. Scores based on visual estimates were adjusted on the basis of hand-separated samples.

Potassium applied in 1960 and 1961 produced a startling regeneration of the clover in plots that had not received K applications previously. The plots that did not receive K maintained very little clover. The clover that remained in these plots showed severe deficiency symptoms and was stunted, so it formed a very small percentage of the total forage on a dry weight basis (Table 7). Samples of the forage were taken in the spring of 1962 to determine the percentage of

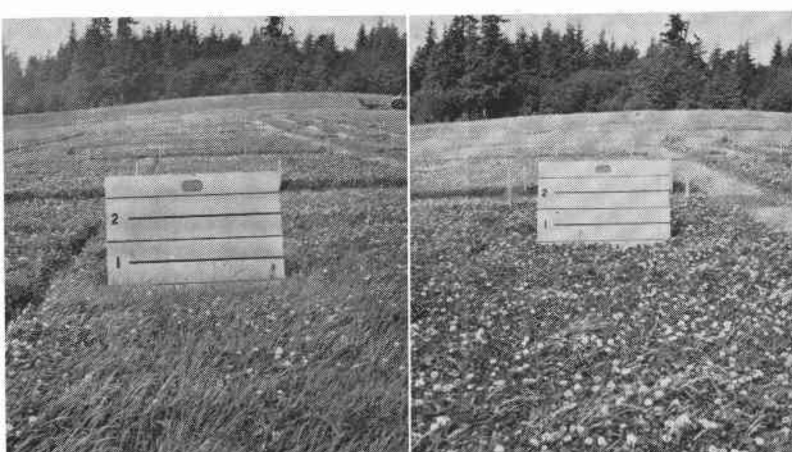

Figure 2. The effect of potassium on increased yield of legumes. The plot at the left did not receive any potassium.

Table 7. EFFECT OF POTASSIUM APPLIED IN 1960 AND 1961 ON REGENERATION OF CLOVER, EXPERIMENT 207

	Treatments		Clover present (6/14/62)
	1957-1959[1]	1960-1962	
			%
1	L_1 P_2 K_2	L_1 P_2 K_2	8
2	L_2 P_2 K_2	L_2 P_2 K_2	20
3	L_3 P_2 K_2	L_3 P_2 K_2	15
4	L_1 P_2 K_0	L_1 P_2 K_0[2]	6
5	L_2 P_2 K_0	L_2 P_2 K_0	2
6	L_3 P_2 K_0	L_3 P_2 K_0	2
7	L_1 P_2 K_0	L_1 P_2 K_2[2]	22
8	L_2 P_2 K_0	L_2 P_2 K_2	28
9	L_3 P_2 K_0	L_3 P_2 K_2	28

[1] See footnote 2, Table 4, for description of treatments.
[2] Treatments 7, 8, 9 were established in 1960 by splitting treatments 4, 5, 6. The previous treatment was continued on one-half the plot; 166 pounds of K per acre were added to the other half of the plot for 1960, 1961, and 1962. Plots were irrigated only during 1957 and 1958.

clover in the mixture. The average percentage of clover on plots that received the second rate of K throughout the experiment was 14%. Those plots that received K during the last two years of the experiment, 1960 and 1961, but none previously, averaged 26% clover. Plots which had never received K averaged 3.5% clover.

The clover on the plots which did not receive K until 1961 was easily regenerated and actually exceeded the percentage of clover composition of the plots which had received K throughout the experiment.

Potassium soil-test values were maintained at the original level of 260 pounds per acre in the surface 6 inches of soil when the second rate of K (166 pounds of K per acre) was applied.

Response from lime. The increase in yield from application of lime was small (2 tons per acre during 2.5 years) as shown in Table 8; the second rate of lime application (6 tons per acre) was adequate for maximum yield. This relatively small yield from lime was statistically significant. The 1957 yield figures are higher than the 1958 yield figures. This was due to luxuriant growth of the orchardgrass and volunteer ryegrass, which may have been caused by release of N from the soil organic matter the first year after application of lime.

Lime was added in increments of 0, 3, 6, 12, and 24 tons per acre. Very little of this lime was leached below the 12-inch depth of soil. Soil tests made in 1961, shown in Table 4 and summarized in Tables 9 and 10, indicate that all of the lime applied at rates of 3 and 6 tons per acre is still in the soil profile. Less than 2 tons appear to have been leached or crop used from those plots receiving 12 tons per acre, and 7

Table 8. Effect of Lime on Forage Yields, Experiment 207

Treatment[1]	Yield 1957	1958	1959[2]	Total
	lb/A	lb/A	lb/A	lb/A
1 L_0 P_2 K_2	9,330	7,830	3,120	20,280
2 L_1 P_2 K_2	9,820	9,020	3,590	22,430
3 L_2 P_2 K_2	11,050	9,800	3,510	24,350
4 L_3 P_2 K_2	11,360	9,520	3,610	24,490
5 L_4 P_2 K_2	12,000	9,490	3,450	24,940

[1] L_1, L_2, L_3, L_4 refer to 3, 6, 12, 24 tons lime per acre respectively applied in 1956. All plots received 88 pounds P and 166 pounds K each year.

[2] Plots were not irrigated in 1959.

Table 9. Chemical Analyses of Soil Sampled in 1961 From Different Lime Treatments, Experiment 207

Lime treatment[1]	Calcium recovered as lime equivalent[2] for each soil depth 0-6″	6-12″	12-36″
	T/A	T/A	T/A
L_0	.43	.43	.37
L_1	3.00	.86	.61
L_2	4.95	1.53	.80
L_3	7.74	2.78	1.04
L_4	13.18	4.00	1.28

[1] L_0, L_1, L_2, L_3, L_4 refer to zero, 3, 6, 12, and 24 tons of lime per acre respectively applied in 1956.

[2] Each me Ca/100 grams of soil equivalent to 0.5 tons lime per acre.

Table 10. Soil pH of Samples Taken in 1961 From Different Lime Treatments

Lime treatment[1]	Samples from four soil depths 0-6″	6-12″	12-24″	24-36″
	pH	pH	pH	pH
L_0	5.0	5.0	5.1	5.4
L_1	5.5	5.3	5.3	5.3
L_2	5.7	5.6	5.2	5.3
L_3	6.1	5.6	5.3	5.2
L_4	6.9	6.1	5.3	5.5

[1] Lime applied in 1956. Rates for each treatment are listed in footnote 1, Table 9.

tons of lime appear to have been lost from plots receiving 24 tons per acre; however, at these higher rates of lime application, the lime was not thoroughly mixed in the soil and representative samples are very difficult if not impossible to obtain.

Response from P. The effects of P on yields during the three-year period are summarized in Table 11. It is evident that P had little effect on yield or changes in balance of clover and grass in this experiment. Leaves and stems of plant samples taken from the P check plots in 1958 averaged 0.32 and 0.24% P for the second and third cuttings, respectively. These levels indicate adequate amounts of P for white clover.

The original level of 12 pounds P per acre, extracted with the sodium bicarbonate (*1*) soil-testing procedure, was maintained on the plots that did not receive P fertilization. By 1961 the P level in the soil had increased to 30 or 40 pounds per acre on plots that had received 44 and 88 pounds of P per acre each year, respectively (Table 4).

Table 11. EFFECTS OF PHOSPHORUS ON FORAGE YIELD, EXPERIMENT 207

Treatment[1]	Yield of forage[2] 1957	1958	1959	Total
	lb/A	*lb/A*	*lb/A*	*lb/A*
1 $L_1 P_0 K_2$	9,660	8,280	2,940	20,880
2 $L_1 P_1 K_2$	10,830	9,220	3,780	23,830
3 $L_1 P_2 K_2$	9,820	9,020	3,590	22,430
4 $L_3 P_0 K_2$	10,020	9,060	3,170	22,250
5 $L_3 P_1 K_2$	11,270	9,230	3,480	23,980
6 $L_3 P_2 K_2$	11,360	9,520	3,610	24,490

[1] See footnote 2, Table 4, for description of treatments.
[2] Optimum soil moisture maintained by sprinkler irrigation in 1957 and 1958. Plots were not irrigated in 1959.

Experiment 206

Information from Experiments 205 and 207, showing that K was of major importance in production of legumes on these soils, was used as a basis for establishing Experiments 206 and 213.

Experiment 206 was established on an area adjacent to Experiment 205 that had received uniform applications of lime and K. This experiment was designed to evaluate time and rate of K application. A single application in the spring was compared with three applications per year—March 15, July 1, and September 1 at rates of 50, 100, and 150 pounds of K per acre. A single fall-versus-spring comparison also was made at the 100-pound rate of K. The data obtained from this experiment during 1958, 1960, and 1961 are given in Table 12. A summary of the results from these treatments follows.

Table 12. EFFECT OF TIME AND RATE OF POTASSIUM ON YIELD OF FORAGE, EXPERIMENT 206

Potassium treatment[1]	Forage yield (dry weight) 1958	1960	1961	Avg.	Rate Avg.
lb/A	lb/A	lb/A	lb/A	lb/A	lb/A
1 Check	8,030	3,610	3,590	5,080	
2 50 spring	8,520	7,060	5,780	7,120	6,910
3 50-3 appl.	8,460	6,780	5,120	6,790	
4 100 fall	9,280	8,710	7,070	8,350	
5 100 spring	8,260	8,310	6,990	7,850	7,950
6 100-3 appl.	9,380	7,550	6,000	7,640	
7 150 spring	9,010	8,340	7,010	8,120	8,020
8 50-3 appl.	9,160	7,060	7,510	7,910	
9 Check[2]	8,600	6,360	4,850	6,600	
10 50 spring	9,510	7,950	6,830	8,100	7,870
11 17-3 appl.	9,560	7,370	6,000	7,640	
12 100 fall	9,440	8,500	7,700	8,550	
13 100 spring	8,840	8,710	7,710	8,420	8,490
14 100-3 appl.	9,570	7,900	6,590	8,020	
15 150 spring	10,020	7,690	7,510	8,410	8,500
16 150-3 appl.	10,175	8,330	7,250	8,590	

[1] All plots had received 8 tons of lime per acre since 1938 and 17 pounds K per acre each year. All plots received 44 pounds P per acre from 1958 to 1961. Plots were reseeded during 1959.

[2] Treatments 9-16 also received 4 tons of manure once every 4 years.

The fall application of 100 pounds of K (treatment 4—9,280 pounds) resulted in higher production for 1958 than a single spring application (treatment 5—8,260 pounds); this difference disappeared by 1961, when the fall application produced a yield of 7,070 pounds while the spring application produced a yield of 6,990 pounds—an insignificant difference. The same effects were evident on the plots that had received previous applications of manure (treatments 12 and 13).

On plots that had not received manure, those with 100- and 150-pound rates of K consistently produced higher yields than plots with 50-pound rates of K. The three-year average yields were 6,910 pounds per acre for the 50-pound K rate, 7,950 pounds per acre for the 100-pound K rate, and 8,020 pounds per acre for the 150-pound K rate. This difference was smaller where manure had been applied over a period of years, with yields of 7,870, 8,490, and 8,500 pounds per acre on treatments receiving 50, 100, and 150 pounds of K, respectively.

Experiment 213

Experiment 213 was established to include a more complete evaluation of time of K application on a series of treatments with a wider range in K soil-test values and to evaluate the effect that K fertilizer might have in "bringing back" the clover in a grass-legume mixture.

The treatments in Experiment 205 were modified to provide this information with the following comparisons:

Treatments were established to compare fall versus spring and one versus two applications of K on plots that had received: (1) K but no manure; (2) K plus manure; (3) no K or manure; and (4) no K but with manure. All K applications reached a total of 166 pounds K per acre each year. All K comparisons were made on plots which received optimum applications of P; previous Mg treatments were disregarded, since response from Mg had not been evident and Mg treatments were discontinued in 1957. This arrangement of treatments made it possible to have two replications for each previous management program where (1) fall versus spring application of K and (2) single versus split application of K (one-half in fall or spring plus one-half applied July 1 versus one single application in the fall or spring) were compared.

Tables 2 and 3 give the K soil-test values for each replication on the different systems of management that were used on these plots before this experiment was started.

The increases in yield from K for 1962 and 1963 and the comparison of yields from different times of K application are presented in Table 13.

The previous applications of manure (10 tons per acre every four years with the last application in 1961) did not have any effect on the yield, K content of forage, or regeneration of clover. This made it permissible to average the yield data for previous treatments of manure and no manure.

Response from K. Response from K was the outstanding effect observed in this experiment. Note the marked increase in yield when treatments 3 through 11 are compared with treatments 1 and 2 that had not received K (Table 13). The previous application of K (treatments 8 through 11) resulted in better yields than treatments 4 through 7 for 1962 during the period of time that the clover was coming back in treatments 4 through 7. However, there was a vigorous stand of clover in these plots by 1963 and, while the difference was small, the plots that had not had K prior to 1962 actually produced the highest yields during 1963.

The clover increased from 10% to 42% on the plots having the first applications of K in the 1962 season, as compared to 51% clover

Table 13. EFFECT OF PHOSPHORUS AND POTASSIUM ON FORAGE YIELDS AND AMOUNT OF POTASSIUM REMOVED, EXPERIMENT 205 (REVISED)

Treatments[1]			Yield of forage		K in forage	
	1956–1961	1962–1963	1962	1963	1962	1963
			lb/A	lb/A	lb/A	lb/A
1	Check	Check	2,510	3,180	......	......
2	Check	P –	2,530	3,060	30	31
3	– K	– K	4,880	5,310	146	140
		(Single application of K)				
4	P –	P K fall	4,840	6,390	111	160
5	P –	P K spring	4,750	6,320	110	159
		(Split application of K—½ applied July 1)				
6	P –	P K fall + July	5,110	6,130	121	130
7	P –	P K spring + July	5,090	5,780	134	127
		(Single application of K)				
8	P K	P K fall	5,590	5,970	158	151
9	P K	P K spring	5,620	5,980	174	161
		(Split application of K—½ applied July 1)				
10	P K	P K fall + July	5,900	5,830	165	137
11	P K	P K spring + July	5,780	6,020	159	142

[1] P refers to 88 pounds P per acre from 1956 through 1961 applied about March 15; 44 pounds P per acre for 1962 and 1963. K refers to 166 pounds K per acre applied each year—fall application about October 15, spring application about March 15, and split application with half applied fall or spring plus half applied about July 1. All plots had received previous applications of lime.

for the plots that had been receiving K since 1956 (on samples taken from the July cutting). By 1963, the second cutting (harvested June 27) had 1% clover in the K check plots as compared to 34% clover on the plots that received K for 1962 and 1963 and 24% clover on those plots receiving K since 1956.

Pictures of these plots taken during the summer of 1963 show the relative balance of clover, grass, and weeds (Figure 2). These photographs also emphasize the effect K fertilizer has on maintaining good quality forage. The high percent of weeds and lack of clover on the plots not receiving K resulted in a marked reduction in quality as well as quantity of forage.

The plots that received K continuously showed a higher rate of K removal in the forage for 1962; however, this difference had largely disappeared by 1963. There were no consistent effects of time of application or split application on the total amount of K removed. However, Figure 3, which shows the percent of K in the forage for each cutting, shows a higher K content for the first two cuttings for those plots receiving a single K application. The split applications (one-half

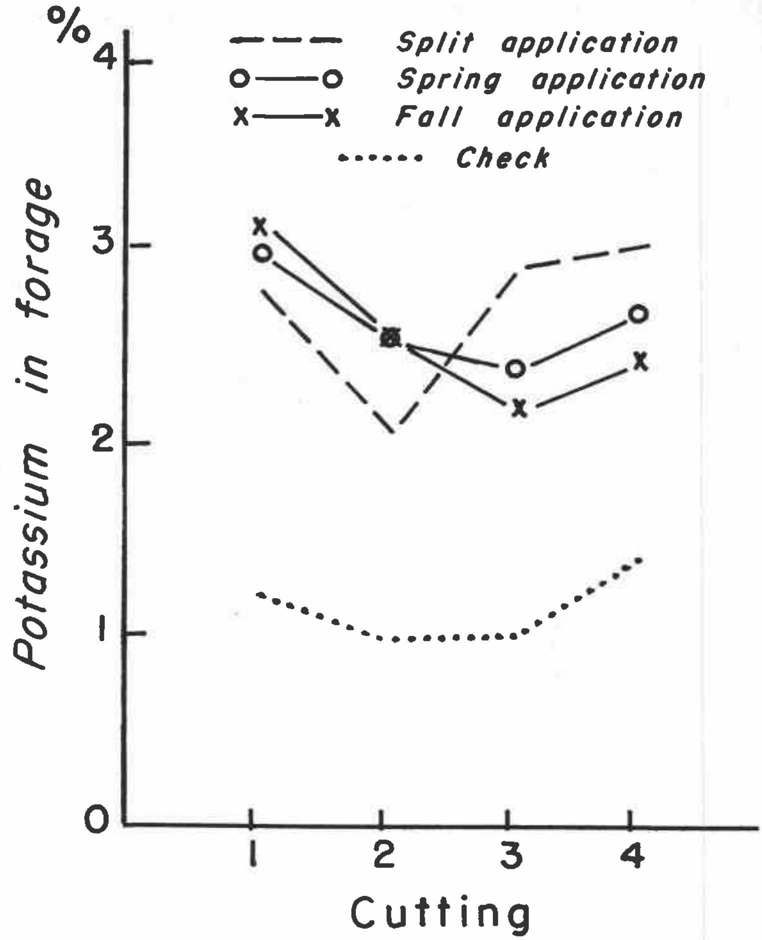

Figure 3. The effect of time of potassium application on the seasonal distribution of potassium in forage (Experiment 213, 1962).

applied July 1) maintained a higher K content during the third and fourth cuttings. Adequate K nutrition in the late summer and fall is important in maintaining legumes in the stand during the winter months when grasses grow more vigorously than legumes. This indicates that fall application of K would be more important under the following conditions: (1) the first year a pasture is fertilized with K; (2) where a lower rate of K fertilization is used; or (3) where a single rate of K applied early in the spring is not maintaining adequate K contents in the forage late in the season.

Response from P. The increase in yield from P averaged 1,000 pounds per acre where P was applied in the presence of adequate K. This can be seen by comparing treatment 3 with treatments 8 through 11 (Table 13). These results are consistent with those obtained during 1956, 1957, and 1958, when the response from P averaged about 1,000 pounds per acre where the plots receiving K were compared with those plots not receiving P and K. It is important to note, in comparing treatment 1 versus 2 (Table 13) that there was no response from P when K had not been applied.

Summary and Conclusions

A series of experiments was carried out at the John Jacob Astor Experiment Station from 1956 through 1963 to evaluate the effects of fertilizers and lime on production and changes in botanical composition of irrigated grass-clover pastures grown on the Astoria soil series. All plots were clipped throughout the growing season to simulate grazing.

1. The application of K fertilizer gave the largest increases in yield and was necessary to maintain legumes in the pasture mixture.
   - A. The application of 100 to 166 pounds of K per acre resulted in maximum yields and satisfactory maintenance of clover. The lower rate of K was adequate on Experiment 206, but there was a significant increase in yield when the rate was increased from 83 to 166 pounds of K per acre in Experiment 207.
   - B. Split applications of K—one-half in the fall or spring, plus one-half on July 1—resulted in higher rates of K in plant samples in the late summer and fall (Figure 3). Adequate K nutrition is important in maintaining legumes in the stand during the winter months when grass competition can be critical.
   - C. Rates of 166 pounds of K per acre each year did not increase K soil-test values to high levels, indicating that this rate was not excessive for the conditions of this experiment.
   - D. Application of K on K-deficient pastures resulted in marked regeneration of clover where some clover was present (Figure 2). Pasture management—frequency and height of cutting or grazing—is also of major importance in maintaining legumes in the stand.
2. A. Rates of 50 to 160 pounds of K per acre in split applications (one-half of the K about July 1)—are recommended for the coastal area.

B. Rates of K application should be reduced when the soil test values start increasing above 400 pounds of K per acre.

C. Fall application of K would be preferable on nonirrigated pastures.

3. Adequate P nutrition is essential for maintenance of legumes in pastures. The soil on this location had a relatively good P supply for white clover. Yield increases from P were small but statistically significant.

4. There was a significant response from lime when the soil test values were at pH 5.1 at the time the experiment started. Lime had a marked effect on maintaining desirable grasses—orchardgrass and ryegrass—and reducing the invasion of weedy grasses—bentgrass and sweet vernal grass. A soil pH of 5.5 to 5.9 is probably adequate for production of white clover on the Astoria soil series in this area.

5. The application of Mg as Mg sulfate did not result in significant increases in yield or improved maintenance of clover in these experiments.

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Appendix

ASTORIA SERIES

The following description of the Astoria soil series is taken from Soil Survey of the Tillamook Area of Oregon, published by the Soil Conservation Service of the United States Department of Agriculture and the Oregon Agricultural Experiment Station in August 1964.

The Astoria soils occur on gently sloping to steep mountainous uplands. They have developed in colluvium or residuum from a variety of sedimentary rocks under coniferous forests. They are at elevations of slightly above sea level to over 2,000 feet, with cool dry summer and cool moist winter climate; annual precipitation usually exceeds 80 inches. The soil varies mainly in depth to bedrock, which ranges from less than three feet to more than six feet. These soils are well drained with moderate permeability. The solum is very strongly acid.

The main associated soils are the Trask, Hembre, and Kilchis series.

Profile of Astoria silt loam in cutover forest, located in SE¼ NW¼ sec. 24, T. 1 S., R. 8 W., W. M. (Trask cutoff road to access road F. B. 12; down this road 400 feet on right side):

A00—2 inches to 0, duff consisting of the litter of bracken fern and the leaves, twigs, and wood of trees.

A11—0 to 9 inches, very dark grayish-brown (10YR 3/2) silt loam, brown (10YR 5/3) when dry; strong, medium fine and very fine granular structure; slightly hard, friable, slightly sticky, slightly plastic; many roots; many interstitial pores; medium-size, firm shot common; very strongly acid (pH 4.8); clear, smooth boundary; 7 to 11 inches thick.

A12—9 to 19 inches, very dark grayish-brown (10YR 3/2) silty clay loam, brown (10YR 5/3) when dry; strong, medium fine and very fine subangular blocky structure; soft, friable, slightly sticky, plastic; many roots; many interstitial pores; few patchy, very thin clay films on vertical ped surfaces; few medium, firm shot; very strongly acid (pH 4.8); clear, smooth boundary; 10 to 12 inches thick.

B21—19 to 28 inches, dark yellowish-brown (10YR 3/4) light silty clay, yellowish brown (10YR 5/4) when dry; moderate, fine and very fine subangular blocky structure; slightly hard, friable, sticky, plastic; many roots; few coarse and medium tubular pores and many exceedingly fine interstitial pores; thin, patchy clay films common; very strongly acid (pH 4.8); clear, wavy boundary; 9 to 13 inches thick.

B22—28 to 45 inches, dark yellowish-brown (10YR 4/4) light silty clay, light yellowish brown (10YR 6/4) when dry; strong, medium fine and very fine blocky structure; slightly hard, firm, sticky, plastic; common roots; many fine and very fine tubular pores and many exceedingly fine interstitial pores; many very thin patchy clay films on peds and in pores; fine fragments of sedimentary rock common; very strongly acid (pH 4.6); gradual, wavy boundary; 13 to 21 inches thick.

B3—45 to 50 inches, yellowish-brown (10YR 5/4) heavy silty clay loam, light yellowish brown (10YR 6/4) when dry; moderate, medium and fine blocky structure; slightly hard, firm, slightly sticky, plastic; common roots; few coarse to medium tubular pores and common, fine to very fine, tubular pores; many thin, patchy clay films on vertical ped surfaces; material is 30 percent medium-size fragments of sedimentary rock; very strongly acid (pH 4.5); clear, wavy boundary; 4 to 8 inches thick.

C—50 to 68 inches, yellowish-brown (10YR 5/6) heavy silty clay loam (color is a mixture of 7.5YR 5/8, 10YR 6/4, and 10YR 7/2, apparently derived from varying rock strata); massive; firm, slightly sticky, plastic; very few roots; material is about 60 percent medium-size fragments of sedimentary rock; very strongly acid (pH 4.8); gradual, wavy boundary; 14 to 22 inches thick.

Dr—68 to 77 inches +, light yellowish-brown (2.5Y 6/4) stratified and broken siltstone coated with dark brown (7.5YR 3/4).