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Alfalfa Fertilization on a Dickson Soil

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by

W. L. PARKS AND L. M. SAFLEY[1]

INTRODUCTION

A suitable crop for forage production is greatly needed for the Highland Rim area. The soils of this area generally are acid and low in fertility in the surface as well as in the subsoil. However, with proper additions of lime and fertilizers, many of these soils will produce good forage yields. Alfalfa produces good yields of high quality forage but requires a rather high level of nutrients in the soil in order to maintain optimum yields over a long period of time. The amount of annual fertilizer additions necessary to maintain a high level of soil nutrients is related to the nutrient-supplying capacity of the soil and the amount of nutrients removed each year in the forage.

The experiments reported herein were conducted on a Dickson silt loam soil at the Highland Rim Experiment Station. These experiments were designed to determine the effect of annual topdressings of phosphorus and potassium on alfalfa yield, life of stand, nutrient removals, and soil test values. The initial soil test for phosphorus was 27 (high) and for potassium was 132 (low). The soil pH was 5.0. Before seeding Buffalo alfalfa at the rate of 20 pounds per acre, the entire experimental area was limed at the rate of 3 tons per acre and fertilized with an application of 32-95-160 (32 lb. N, 95 lb. P_2O_5, and 160 lb. K_2O), and 20 pounds of borax per acre. The first seeding in the fall of 1953 failed and the experiment was reseeded in the fall of 1954 with the annual topdressing fertilizer treatments starting in the spring of 1955.

Soil samples were collected from each plot at the beginning of the experiment and again each spring just prior to the annual fertilizer additions. Plant samples were collected from each cutting to determine the amount of nutrients removed in the forage. At the end of the experiment, soil samples were obtained at different depths in the soil profile to determine the zones of nutrient accumulation and depletion. In addition to the fertilizer treatments studied, the entire experimental area received annual applications of 20 pounds of borax per acre.

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RESULTS AND DISCUSSION

Forage yields

One phase of the experiment was to determine the hay yields produced where annual topdressings of 0, 60, 120, and 180 pounds

Table 1. Alfalfa forage yields as influenced by annual applications of different rates of phosphorus and potassium.

Tmt. No.	Treatment	1955	1956	1957	1958	4-year average
	Lb.	Tons Of Alfalfa Forage Per Acre				
1	0-0-0	3.81	2.23	3.12	0	2.29
2	0-0-100	4.62	3.36	3.94	1.72	3.41
3	0-0-200	4.10	2.86	3.98	2.14	3.27
4	0-0-300	4.41	3.24	4.30	3.67	3.91
5	0-0-400	4.83	3.56	4.82	3.85	4.27
6	0-60-0	4.50	3.06	2.89	0	2.61
7	0-60-100	4.56	3.33	4.42	2.48	3.70
8	0-60-200	4.46	3.56	4.61	4.00	4.16
9	0-60-300	4.50	3.99	4.97	4.11	4.39
10	0-60-400	4.32	3.62	5.25	4.11	4.33
11	0-120-0	4.18	2.71	2.85	0	2.44
12	0-120-100	3.99	3.22	4.52	2.43	3.54
13	0-120-200	4.55	3.54	4.86	4.11	4.27
14	0-120-300	4.48	3.68	4.57	4.33	4.27
15	0-120-400	4.17	3.45	4.96	4.54	4.28
16	0-180-0	4.67	3.58	2.59	0	2.71
17	0-180-100	4.40	3.44	4.28	2.29	3.60
18	0-180-200	4.66	3.82	4.85	3.89	4.31
19	0-180-300	4.40	3.78	4.77	4.89	4.46
20	0-180-400	4.14	3.59	4.93	4.20	4.22
Average For Phosphorus Additions At All Levels Of Potassium						
Lb. P_2O_5/A						
	0	4.35	3.05	4.03	2.84	3.57
	60	4.47	3.51	4.43	3.67	4.02
	120	4.27	3.32	4.35	3.85	3.95
	180	4.45	3.64	4.28	3.81	3.90
L. S. D. (5%)		N.S.	0.29	N.S.	0.45	0.27
(1%)		N.S.	0.40	N.S.	0.63	N.S.
Average for potassium additions at all levels of phosphorus						
Lb. K_2O/A						
	0	4.29	2.89	2.86	0	2.51
	100	4.39	3.34	4.29	2.23	3.56
	200	4.44	3.45	4.57	3.53	4.00
	300	4.45	3.67	4.65	4.24	4.25
	400	4.36	3.56	4.99	4.17	4.27
L. S. D. (5%)		N.S.	0.32	0.38	0.45	0.30
(1%)		N.S.	0.46	0.52	0.63	0.42

of P_2O_5 per acre and 0, 100, 200, 300, and 400 pounds of K_2O per acre were applied in all combinations. Concentrated superphosphate and muriate of potash were mixed in the proper proportions and applied in late February or early March of each year. The hay yields obtained each year from the different fertilizer treatments, as well as the 4-year average, are shown in Table 1.

These data show that potash was more limiting than phosphate at this particular location. Fairly good alfalfa yields were obtained without annual applications of phosphate when ample potash was applied. In 2 of the 4 years, a significant yield increase from phosphate was obtained and the 4-year average yield showed that yields with 60 pounds per acre of P_2O_5 were significantly higher than the yields from the no-phosphate treatments.

Annual applications of potash resulted in significant yield increases every year except the first year. No significant differences among the different potash treatments were observed the first production year. During the second and third production years, it appeared that an annual application of 100 pounds of K_2O per acre was sufficient for good yields. However, as shown in the 1958 yields as well as in the average yields for the 4 years, an annual application of slightly more than 200 pounds of K_2O per acre would be required for optimum alfalfa production over several years. As will be shown later, it is necessary to consider soil-test values along with crop removals and fertilizer additions in arriving at the desired fertilizer application rate for the highest alfalfa yields over longer periods of time.

Where alfalfa received no annual topdressing of potash the stand gradually disappeared. In the latter part of the third production year, the area was covered with crabgrass, and no alfalfa was present. Yields were not obtained on these areas during the fourth year.

Soil-test values

The following are shown in Table 2: 1) the average phosphorus and potassium soil test values for the plots of each treatment; 2) the average values for the different levels of phosphorus at all levels of potash; and 3), the average values for the different levels of potash at all levels of phosphorus. The average values for the different rates of phosphorus and potassium fertilization are shown graphically in Figure 1.

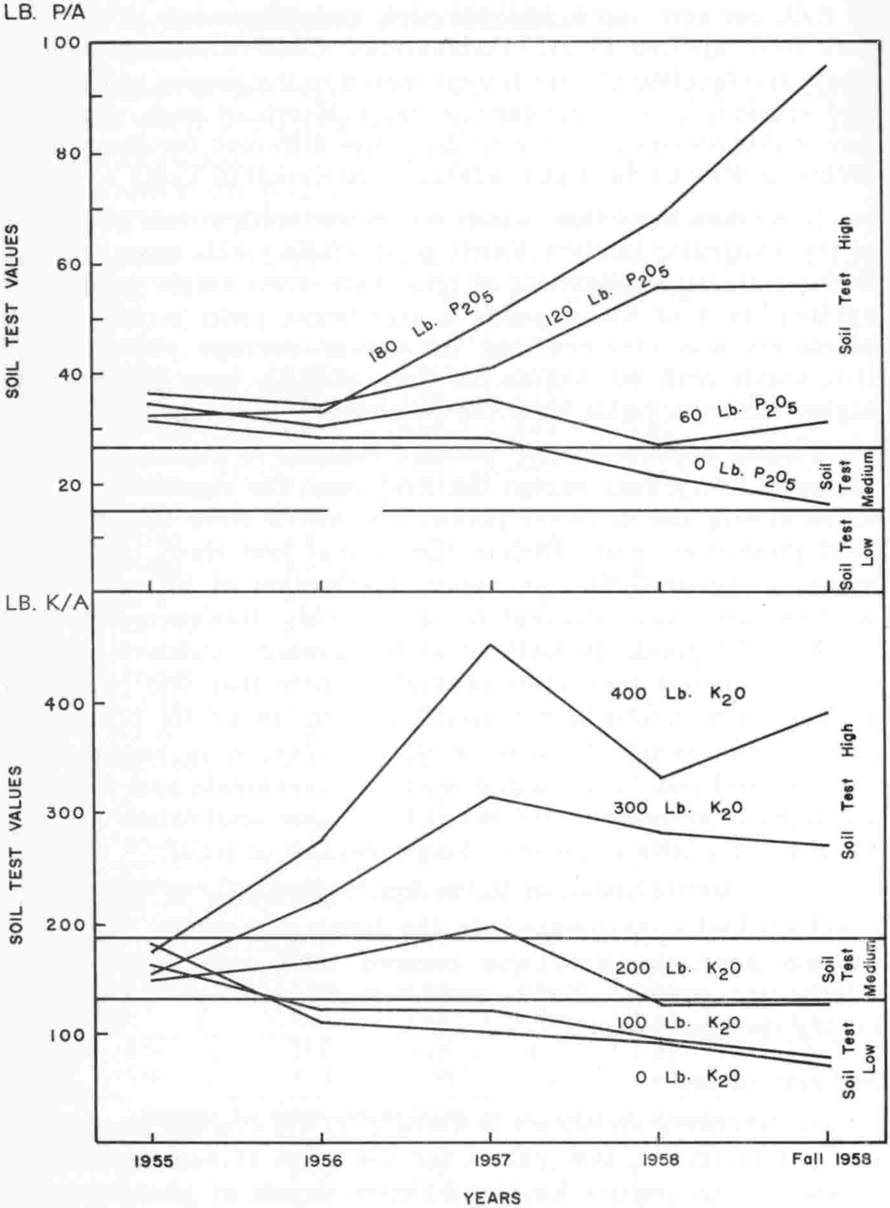

Figure. 1. Average phosphorus and potassium soil test values for each year and at the conclusion of the experiment.

The average soil-test values for phosphorus showed a slight decrease each year where no annual phosphate additions were made. As the soil phosphorus level declined, so did yield when soil-test values approached a medium level. By 1958 the soil test value for phosphorus had dropped well into the medium level, and a difference of 0.83 ton of forage yields was observed between the unphosphated treatment and the treatments receiving 60 pounds of P_2O_5 per acre per year. Annual applications of 60 pounds of P_2O_5 per acre maintained the average phosphorus soil-test values at a high level (above 25).

Yield data indicate that maintaining the soil test values for phosphorus at a high level is desirable. Annual application rates of 120 and 180 pounds of P_2O_5 per acre gradually increased the average phosphorus soil test values, but did not increase yields beyond that obtained at 60 pounds of P_2O_5 per acre.

The average soil test values for potassium were medium at the beginning of the experiment. In the treatments receiving no annual potassium applications, the soil test values dropped to about 75 pounds per acre; they remained at this level throughout the experiment. As pointed out before, alfalfa disappeared in these treatments during the third year. Annual applications of 100 pounds of K_2O per acre failed to maintain the available soil potassium level, as it also decreased to about the 75 pound per acre level. At the end of the fourth production year, alfalfa had also disappeared from these treatments.

Annual applications of 200 pounds of K_2O per acre resulted in a small gradual increase in the potassium soil test values during the first 2 production years. Moisture conditions were favorable for alfalfa in 1957 and 1958 as shown by yields of 4.5 to 5.0 tons per acre in Table 1. Even though 200 pounds of K_2O per acre was added, more than that was removed at these yield levels. The higher removals in 1957 and 1958 were reflected in a lower potassium soil-test value at the spring and fall sampling in 1958.

This indicates that even though the annual application rate of 200 pounds of K_2O per acre produced high alfalfa yields and soil-test values increased slightly for the first 2 years, years of very high yields may deplete the soil potassium to a low level that will adversely influence the vigor and life of the alfalfa stand. Annual applications of 300 and 400 pounds of K_2O per acre produced high alfalfa yields and soil-test values showed increases in the available soil potassium levels even after years with very high yields. The higher production in 1957 also resulted in lower available soil potassium levels at the beginning of the next year even at the higher rates of K_2O.

Table 2 shows that the treatments that received no phosphate

Table 2. Phosphorus and potassium soil test values for each year and at the conclusion of the experiment.

Tmt. No.	Annual treatments	PHOSPHORUS* 1955	1956	1957	1958	Fall 1958	POTASSIUM* 1955	1956	1957	1958	Fall 1958
	Lb.	Lb. P per acre					Lb. K per acre				
1	0-0-0	26	29	23	26	17	197	126	104	93	74
2	0-0-100	33	26	28	23	17	142	122	122	89	102
3	0-0-200	27	31	27	19	16	148	174	226	158	180
4	0-0-300	33	30	28	17	17	166	216	378	331	370
5	0-0-400	38	28	32	21	16	161	270	504	371	513
6	0-60-0	33	27	31	25	33	182	103	99	98	60
7	0-60-100	41	33	45	26	32	170	116	122	80	64
8	0-60-200	34	32	30	28	34	152	165	187	114	137
9	0-60-300	31	34	35	30	33	138	173	296	238	242
10	0-60-400	34	25	34	25	23	186	258	540	322	353
11	0-120-0	41	31	46	78	61	168	103	100	73	77
12	0-120-100	32	32	36	47	51	170	130	134	112	70
13	0-120-200	44	43	45	59	64	153	152	196	117	89
14	0-120-300	34	35	44	50	53	167	255	312	294	258
15	0-120-400	31	32	36	44	51	157	286	422	382	367
16	0-180-0	35	36	46	71	137	168	114	98	98	72
17	0-180-100	34	32	54	62	88	150	130	124	90	78
18	0-180-200	30	39	59	71	83	136	169	180	108	105
19	0-180-300	35	32	55	72	87	152	246	282	254	206
20	0-180-400	28	30	38	64	88	206	300	360	290	332

* From 0-to-6-inch soil samples obtained each year before annual fertilizer additions and in the fall of 1958 after all forage harvesting was completed.

Phosphorus averages at all levels of potassium

Lb. P_2O_5/A	1955	1956	1957	1958	Fall 1958
			Lb. P Per Acre		
0	31	29	28	21	17
60	35	30	35	27	31
120	36	34	41	56	56
180	32	34	51	68	96

Potassium averages at all levels of phosphorus

Lb. K_2O/A	1955	1956	1957	1958	Fall 1958
			Lb. K Per Acre		
0	179	112	100	90	71
100	158	124	126	93	78
200	147	165	197	124	128
300	156	222	317	279	269
400	177	278	456	341	391

tested higher in potash than did the other treatments that received the same rate of potash plus some phosphate. Likewise, the treatments that received no potash generally tested higher in phosphate than did the other treatments that received the same phosphate application plus some potash. This indicates that balanced fertilization is necessary for best yields of alfalfa, and is most essential in obtaining the maximum benefits from the added fertilizers.

The data in Tables 3 and 4 show the soil-test values at the conclusion of the experiment expressed in parts per 2 million for available phosphorus and potassium at several soil depths for the different treatments.

Table 3. Available phosphorus throughout the profile of a Dickson soil after 4 years of potassium topdressings at various rates*

Tmt. No.	Treatment	Total lb. P applied per acre	Soil Levels in Inches 0-1	1-3	3-6	6-12	12-18	18-24
	Lb.				Parts per 2 million			
1	0-0-0	0	25	18	14	6	3	4
2	0-0-100	0	23	18	14	6	3	3
3	0-0-200	0	21	15	14	6	3	3
4	0-0-300	0	23	17	16	6	3	4
5	0-0-400	0	23	16	14	7	3	4
6	0-60-0	104	96	23	18	6	3	4
7	0-60-100	104	75	30	18	6	2	3
8	0-60-200	104	79	25	25	6	4	5
9	0-60-300	104	65	32	23	7	4	6
10	0-60-400	104	59	19	14	6	2	3
11	0-120-0	208	210	46	21	8	5	5
12	0-120-100	208	182	32	20	8	4	7
13	0-120-200	208	184	57	29	12	4	5
14	0-120-300	208	148	49	24	7	4	6
15	0-120-400	208	173	35	21	8	3	6
16	0-180-0	312	308	209	32	10	6	7
17	0-180-100	312	297	67	32	13	4	9
18	0-180-200	312	255	77	29	15	6	7
19	0-180-300	312	283	80	26	13	5	8
20	0-180-400	312	292	74	29	18	4	9
			Phosphorus Averages					
	0	0	23	17	15	6	3	4
	60	104	75	26	20	6	3	4
	120	208	179	44	23	9	4	6
	180	312	287	101	30	14	5	8

* Values are means of all replications and are expressed in parts per 2 million (Equivalent to lb. per acre in top 6 inches of soil).

The available phosphorus values in Table 3 indicate an accumulation of the applied phosphorus in the surface inch of the soil. There had been some movement of the surface-applied phosphorus into the 1-to-3-inch soil level; however, the 3-to-6-inch layer was at approximately the same level as when the experiment was started except that the phosphorus values were lower for the no phosphorus and 60 pound per acre treatments. This could be accounted for by crop removals.

Table 4. Available potassium throughout the profile of a Dickson soil after 4 years of potassium topdressings at various rates.*

Tmt. No.	Treatment	Total lb. K applied per acre	Soil Levels in Inches 0-1	1-3	3-6	6-12	12-18	18-24
	Lb.		Parts per 2 million					
1	0-0-0	0	158	62	54	80	100	96
2	0-0-100	332	250	97	56	65	94	92
3	0-0-200	664	480	180	80	82	98	92
4	0-0-300	996	684	460	206	120	116	127
5	0-0-400	1328	812	616	344	136	103	104
6	0-60-0	0	130	48	44	72	82	70
7	0-60-100	332	188	70	42	50	68	70
8	0-60-200	664	280	158	75	76	102	109
9	0-60-300	996	448	292	140	94	103	114
10	0-60-400	1328	660	420	206	127	112	122
11	0-120-0	0	198	54	52	68	85	79
12	0-120-100	332	171	52	48	75	98	96
13	0-120-200	664	207	80	56	72	92	101
14	0-120-300	996	455	306	160	79	94	104
15	0-120-400	1328	594	420	256	126	113	126
16	0-180-0	0	166	56	51	81	84	90
17	0-180-100	332	190	66	50	72	90	82
18	0-180-200	664	220	103	68	90	104	106
19	0-180-300	996	414	230	122	109	114	120
20	0-180-400	1328	590	401	201	144	108	110
	Potassium Averages							
	0	0	163	55	50	75	88	84
	100	332	200	71	49	66	88	85
	200	664	297	130	70	80	99	102
	300	996	500	322	157	101	107	116
	400	1328	664	464	252	133	109	116

* Values are means of all replications and are expressed in parts per 2 million (Equivalent to lb. per acre in top 6 inches of soil).

The available potassium values in Table 4 show that the 0-to-1-inch soil layer has the highest potassium content of any soil layer tested within each of the treatments. The potassium content of the 1-to-3-and-3-to-6-inch layers indicates movement of some of the surface-applied potassium into these layers. These data indicate that over the 4-year period, very little if any of the applied potassium moved below the plow layer (0-6 inches). This would indicate that leaching losses are very small even at the high application rates. There is some indication that the alfalfa lowered the subsoil potassium level in the zero and 100-pound per acre treatments.

Nutrient content of forage

Alfalfa forage has a high mineral content and high yields result in the removal of large amounts of the more common fertilizer nutrients. Chemical analyses have shown that each ton of air-dry alfalfa forage removes about the equivalent of:

90 pounds of agricultural limestone
85 pounds of 60% potash
60 pounds of 20% phosphate
1.8 pounds of borax

plus many other mineral elements in smaller quantities.

The amounts of P_2O_5 and K_2O equivalents removed each year were determined by chemical analyses; the results are shown in figures 2 and 3. The data in Figure 2 indicate that annual phosphate additions resulted in higher phosphate removals than when no phosphorus was applied. This was due partly to increased yields and partly to a higher phosphate content in the forage from the treatments receiving the phosphate additions. For the 4 years, average amounts equivalent to 36, 48, 51, and 55 pounds of P_2O_5 were removed from each acre each year for the 0-, 60-, 120-, and 180-pound P_2O_5 per acre treatments respectively.

The data in Figure 3 indicate that annual potassium additions greatly increased the potassium removals in the forage. This was due primarily to increased yields and partly to an increase in the potassium content of the forage from treatments receiving annual potassium additions. The high forage yields during the first year of the experiment resulted in high potassium removals. This was reflected in lower yields and lower removals for the subsequent years in the treatments receiving no potash.

The potassium removed in the forage from the 100 pounds of K_2O per acre treatments was much greater than the annual additions. This removal gradually depleted the soil potassium supply and resulted eventually in loss of the alfalfa stand. Annual applications of 200 pounds of K_2O per acre more nearly approached the alfalfa needs for potash, but even this was slightly lower than the amounts necessary for sustained alfalfa production. This was

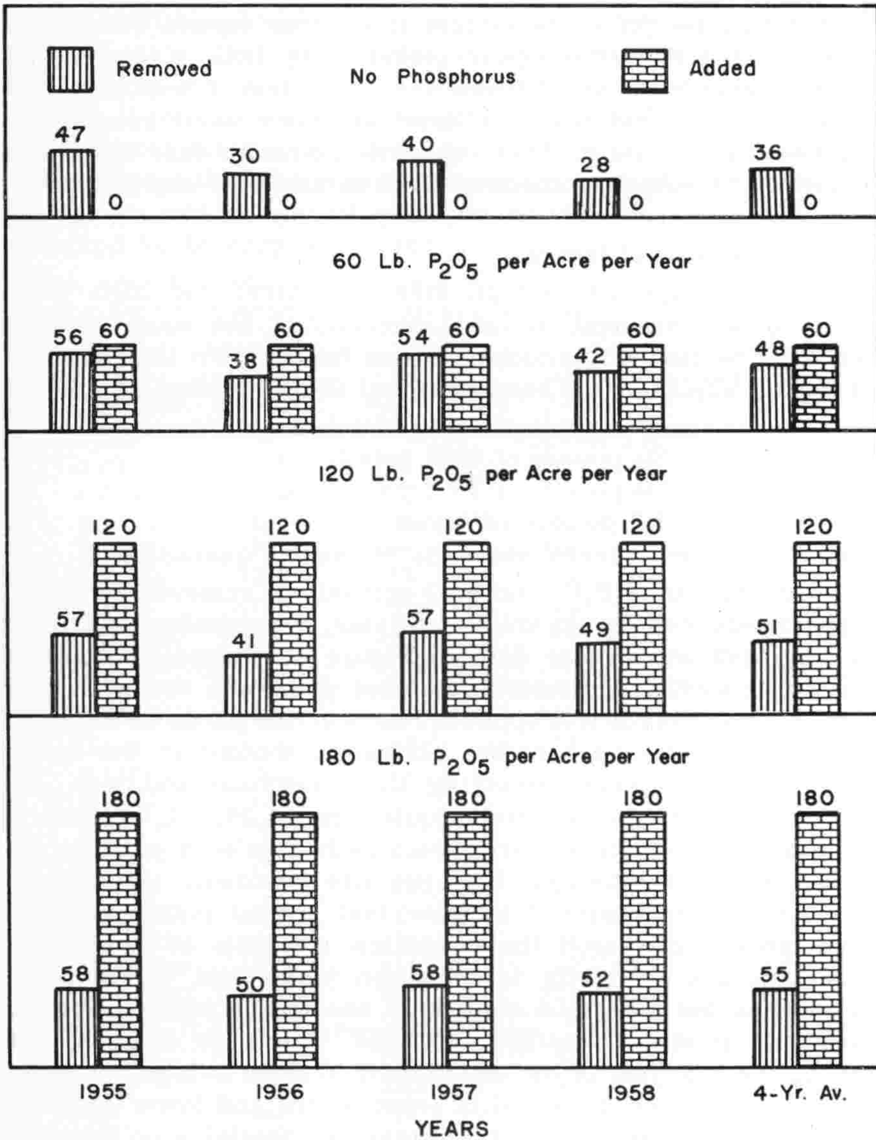

Figure 2. The amounts of P_2O_5 added to the soil and removed in the forage each year.

shown by potash removals in the forage and accompanying soil-test results.

Annual applications of 300 and 400 pounds of K_2O per acre supplied more potassium than was removed, and resulted in increased levels of available soil potassium over the 4 years.

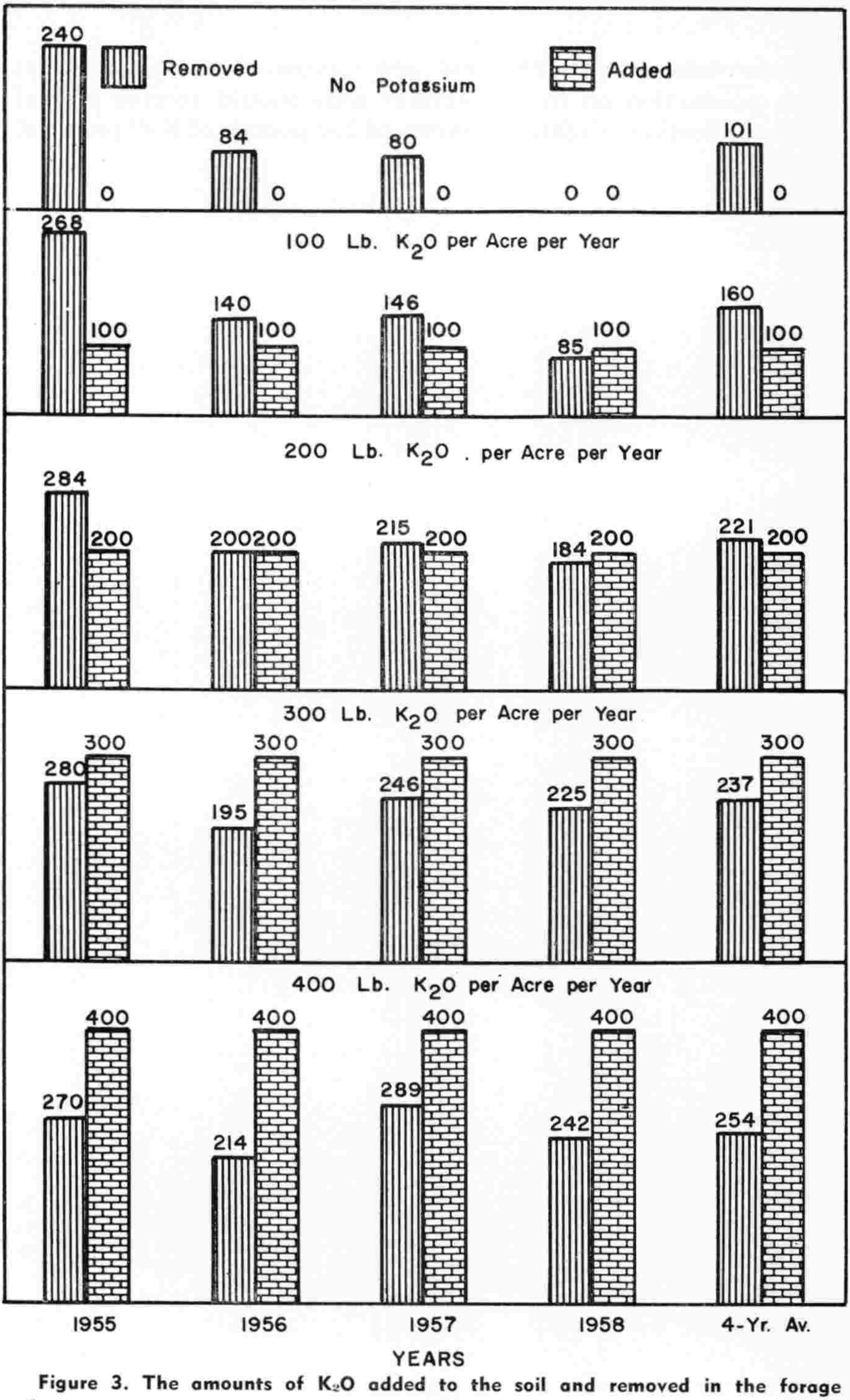

Figure 3. The amounts of K_2O added to the soil and removed in the forage each year.

These data, along with yield and soil-test data, indicate that alfalfa production on this or similar soils should receive annual potash applications slightly in excess of 200 pounds of K_2O per acre.

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