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Studies of Fertilizer Phosphorus and Potassium as Affecting Yield and Mineral Uptake by Red Clover-Timothy (Hay) and Ladino Clover-Orchardgrass (Pasture) Mixtures

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採草型（アカクロバー・チモシー混播）ならびに放牧型（ラデノクロバー・オーチャードグラス混播）植生における燐酸および加里施肥が収量，養分吸収に及ぼす影響

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Introduction

There has been an increasing growth in the demand for dairy and beef products in Japan since 1950. Throughout the cool humid regions of the world, skillfully managed perennial legume-grass forage mixtures are a primary source of dependable, economical, nutritious livestock feed. Both research and field demonstrations are showing that large areas of relatively unused land in eastern Hokkaido is suitable for growing existing improved varieties of cool season legumes and grasses.

In the grassland development, the most difficult problem on unused, unimproved, unfertile volcanic ash soils is that of establishing dense, vigorous stands of the improved legumes such as alfalfa, red clover and ladino clover and grasses such as improved leafy orchardgrass and timothy. The chemistry of phosphate (P) fixation and resulting low P availability is the primary obstacle.

Physical difficulties of rugged terrain, steep slope and inadequate roads are secondary. Unless adequate P is supplied initially in a method to insure availability, the establishment too often is ineffective and the large yield potential of high quality forage is lost.

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Most of Hokkaido's unused volcanic ash soils are acid, low in fertility, especially low in available P. These soils are unusually high in active aluminum which reacts chemically, fixing applied soluble P, rendering it relatively unavailable. On soils low in available P and with a great capacity to fix soluble P, the principle of applying large amounts of fertilizer P in precision bands before planting has been highly effective in the establishment and in providing P to sustain high yields of improved legume-grass forage (2, 3). OOHARA *et al.* (2) and PARSONS *et al.* (3) each showed that when about 45 kg P/ha was supplied in bands before seeding, the annual addition of P as a topdressing did not appreciably increase dry matter yields or P composition of the legume-grass association.

This investigation studied the effect of rates and method of fertilizer P placement and the effect of annual topdressing of NPK on dry matter yield, chemical composition and PK input-output balance of perennial legumes and grasses.

Table 1. Meteorological data during ten years from 1956 to 1965

	Jan.	Feb.	March	Apr.	May	June	July
Mean Temp. (°C)	− 5.2	− 4.5	− 0.8	5.1	9.7	12.2	16.0
Max. Temp. (°C)	− 0.9	− 0.4	2.8	9.6	14.7	16.0	19.3
Min. Temp. (°C)	−10.6	−10.0	− 5.2	0.6	5.4	9.0	13.4
Precipitation (mm)	98.8	80.7	104.2	161.2	138.0	180.0	158.9
Humidity (%)	67	68	71	71	77	87	90
No. of fine days	9.2	7.2	9.6	9.1	8.8	10.7	13.0
No. of cloudy days	2.4	2.0	3.2	4.2	3.8	4.6	4.3
No. of foggy days	0.7	0.5	0.7	1.5	1.2	1.4	1.1
Hour of sun shine (hrs)	168.5	175.5	204.4	211.8	211.3	148.1	130.6
Average wind velocity (m/sec.)	3.5	3.3	3.4	3.7	3.4	2.5	2.2

	Aug.	Sept.	Oct.	Nov.	Dec.	Aver. or Total	May–Sept.
Mean Temp. (°C)	18.5	15.6	10.3	4.5	− 1.3	6.7	14.4
Max. Temp. (°C)	21.7	19.4	14.8	9.0	2.7	10.7	18.2
Min. Temp. (°C)	15.8	12.1	5.8	− 0.3	− 5.9	2.5	11.1
Precipitation (mm)	230.9	254.6	174.1	127.8	82.2	1791.6	962.4
Humidity (%)	88	82	75	65	65	76	84.8
No. of fine days	11.8	12.6	9.5	9.3	10.2	121.0	11.4
No. of cloudy days	4.7	6.5	4.5	4.1	2.2	46.5	4.8
No. of foggy days	2.0	2.4	1.8	1.1	0.3	14.7	1.6
Hour of sun shine (hrs)	128.9	160.1	177.4	162.4	156.2	2035.1	155.8
Average wind velocity (m/sec.)	2.2	2.9	3.1	3.4	3.4	3.1	2.7

Materials and Methods

The summer climate in the region south and east of Obihiro, is cool with high humidity and frequent rainfall (Table 1).

Few days are suitable for field curing of hay because of excessive Pacific Ocean fog. Summer rainfall exceeds 900 mm and annual rainfall is about 1800 mm. Because of the nearness to the Pacific Ocean, the frost free period is about 160 days. October and November are relatively dry with bright clear days. The mean temperature for the period December through March is below freezing. The climate is somewhat similar to the Maine coastal region, U.S.A. (2).

Experiment 1. (See Table 2 about soil description). A uniform soil treatment of 2.5 ton/ha of dolomitic limestone; 240 kg ammonium chloride and 160 kg of

Table 2. Chemical condition of soil at Toyokoro field (fine sandy loam derived from Tokachidake C series over diluvial deposits, volcanic ash fall).

	Percent organic matter	pH H_2O	pH KCl	N (%)	Available P (ppm)	P fixing capacity	Exchangeable cations mg/100 g			
							Ca	Mg	K	Na
0–15 cm	12.0	6.0	4.2	0.99	2.80	1785	3.1	0.46	0.15	0.05
15–30 cm	8.6	5.8	4.14	0.65	0.70	2165	2.2	0.17	0.12	0.03

sulfate of potash (72 kg K), was broadcast and disked into the soil before applying the phosphate fertilizer increments. On July 12, 1965, three varieties of alfalfa (Du Puits, Rhizoma and Williamsburg) and Climax timothy were seeded separately at the rate of 15kg/ha on plots which had received superphosphate at the rate of 44 and 88 kg P/ha in precision bands 5 cm deep and 20 cm apart, and a third treatment of 88 kg P/ha broadcast and mixed into the seedbed. Plots 0.5×5 m with 3 replicates were harvested October 15, 1965.

Experiment 2. (See Table 2 about soil description). A uniform soil treatment of 2.5 ton/ha of dolomitic limestone; 240 kg ammonium chloride and 160 kg sulfate of potash (72 kg K), was broadcast and disked into the surface soil. Also disked into the soil were superphosphate (0, 300, 600, 900, 1200 and 1500 kg/ha) supplying 0, 26.16, 52.32, 78.48, 104.64 and 130.8 kg P/ha. On June 4, 1965, Kenland red clover and Climax timothy (hay mixture) and Ladino clover-Massachusetts Hardy orchardgrass (pasture mixture) were seeded by the broadcast method. In the spring of 1966 the plots were split to topdressed and not topdressed. A fertilizer topdressing supplying 36 kg N, 28.8 kg P and 55 kg K was added in 1966 and again in 1967.

One-half of this annual topdressing was applied in early spring, one-fourth after the first and one-fourth after the second harvest.

Plots 2×5 m with 3 replicates were harvested in August 1965 and in August and mid-june 1966, and in early August and early October 1967.

Results and Discussion

Experiment 1. Band placement of the superphosphate was much more effective than the broadcast and soil mixed method in increasing yield and phosphorus (P) uptake by each of the three alfalfa varieties (Table 3). Banding 44 kg P/ha produced greater alfalfa yields, and in 2 of the 3, greater P uptake

Table 3. Effect of placement and rate of superphosphate at seeding on yield, N P K composition and uptake (kg/ha).

	Method	P	Dry	Percent			Uptake			Percent of appleid	
		kg/ha	matter	N	P	K	N	P	K	P	K(72)
Du Puits alfalfa	band	44	1040	3.04	0.217	2.64	31.59	2.26	27.41	5.2	38.1
		88	1860	2.96	0.247	2.52	55.06	4.59	46.82	5.2	65.0
	broad-cast	88	930	2.60	0.151	2.81	24.20	1.40	26.11	1.6	36.3
Rhizoma alfalfa	band	44	920	2.99	0.228	2.74	27.52	2.10	25.23	4.8	35.0
		88	1030	3.12	0.314	2.67	32.09	3.23	27.52	3.7	38.2
	broad-cast	88	550	2.57	0.303	3.14	19.64	1.67	17.26	1.9	24.0
William-sburg alfalfa	band	44	1080	2.91	0.195	2.60	31.45	2.11	28.06	4.8	39.0
		88	1110	2.81	0.300	2.65	31.16	3.33	29.36	3.8	40.8
	broad-cast	88	820	2.90	0.281	3.03	23.81	2.30	24.87	2.6	34.5
Timothy Scottish	band	44	3670	2.53	0.182	3.06	92.85	6.68	112.41	15.2	156.0
		88	3320	2.52	0.216	3.04	83.76	7.17	100.76	8.2	139.9
	broad-cast	88	3970	2.49	0.260	3.19	98.85	10.32	126.72	11.7	176.0

than 88 kg of broadcast P. In contrast, greater timothy yield and P uptake resulted from broadcast than from band placement, although greater relative P uptake occurred with 44 kg P banded than with 88 kg P broadcast. Reduction in yield at 88 as compared to 44 kg P/ha banded indicated some injury may have occurred in the timothy seedling stage. Phosphorus removal in seedling year's growth of forage amounted to about 4 to 5 percent of the banded P for alfalfa and 8 to 15 percent for timothy.

Plant removal of potassium by the seedling year's growth was extremely great for timothy ranging from 140–176 percent of the amount of fertilizer K supplied (Table 3). This points up the need for liberal topdressing of fertilizer K where legumes are grown in association with grasses, and specifically for timothy. A significant differences at 1% level on the yield of varieties of alfalfa and between fertilizer treatments were found, and there were any significant differences between blocks of both species (Table 4 a, b).

Experiment 2. Dry matter was increased in 1965, the seeding year, by each increment of fertilizer P for both the hay type and the pasture type forage

Table 4-a. Analysis of variance on the yield (kg/ha as dry matter) between varieties of alfalfa and blocks

Source of variance	D. F.	Sum of squares	Mean square	F
Main Plot:				
Varieties	2	900467	450238.5 **	
Plots	2	3472	1736	
Error (A)	4	2145	536.25	
Sub Plot:				
Treatments	2	1032267	516133.5 **	
T × V	4	1049133	262283 **	
Error (B)	12	24533	2044.41	

Table 4-b. Analysis of variance on the yield of timothy

Source of Variance	D. F.	Sum of squares	Mean square	F
Total	8	675918		
Between fertilizer and treatments	2	635000	317500 **	
Between plots	2	3533	1766.5	
Error	4	37385	9346.25	

* Significance at 5% level
** Significance at 1% level

(Tables 5 and 6).

Hay type. The p content of hay type plants in 1965 was far below the acceptable level, being 0.101, 0.124 and 0.122% for applications of 26.16, 52.32 and 78.48 kg P/ha, respectively, and was only 0.146 and 0.147 for 104.6 and 130.8 kg P/ha. This response in yield and in P content in the seeding year on this low P soil emphasizes (1) the need for liberal initial applications of fertilizer P, and (2) P applied in concentrated bands to avoid losses in P availability resulting from P fixation. (Note that in experiment 2, all phosphate was mixed into the soil resulting in maximum soil-fertilizer P contact and maximum P fixation or minimum available P).

In the second and third years, each increment of fertilizer P produced an increase in dry matter forage yield and in total P uptake (Table 5). Percent P increased markedly in 1966 and 1967 over that of 1965 at the 0 and lower levels of applied P, indicating increased exploitation of fertilizer and native soil P as the root systems enlarged. Increased hay type dry matter yields in 1966 and 1967 produced by higher increments of fertilizer P were relatively low in percent P, suggesting that the initial rates of broadcast fertilizer P (80 to 130 kg P/ha) were too low to supply the P required for sustained perennial forage production

Table 5. Effects of rates of fertilizer phosphorus on red clover-timothy hay mixture, dry matter (ton/ha), and P uptake (% of applied P).

1965

Applied P kg/ha	Dry matter	% P	kg P	% applied P uptake	Applied P kg/ha	Dry matter	% P	kg P	% applied P uptake
0	.98	.091	.89		0	.98	.091	.89	
26.16	2.89	.101	2.919	11.2	26.16	2.89	.101	2.919	11.2
52.32	3.18	.124	3.943	7.5	52.32	3.18	.124	3.943	7.5
78.48	3.60	.122	4.392	5.6	78.48	3.60	.122	4.392	5.6
104.64	4.13	.146	6.030	5.8	104.64	4.13	.146	6.030	5.8
130.80	4.35	.147	6.395	4.9	130.80	4.35	.147	6.395	4.9
F Value	12.579 **	21.513 **	21.929 **	38.54 **		12.579 **	21.513 **	21.929 **	38.54 **
LSD (5%)	1.00	0.004	1.372	1.330		1.00	0.004	1.372	1.330
LSD (1%)	1.42	0.007	1.952	1.935		1.42	0.007	1.952	1.935

1966

	Not topdressed					Topdressed			
0	1.37	.169	2.31		(28.78)	4.14	.189	7.81	27.1
0	4.98	.162	8.05	30.8	(54.94)	9.60	.193	18.52	33.7
0	6.51	.162	10.53	20.1	(81.10)	11.49	.196	22.52	27.8
0	7.69	.184	14.18	18.1	(107.26)	13.64	.197	26.86	25.0
0	8.13	.173	14.04	13.4	(133.42)	14.12	.207	29.24	21.9
0	8.20	.192	15.78	12.1	(159.58)	15.47	.183	28.31	17.7
F Value	671.6 **	30.72 **	671.6 **	139.94 **		916.57 **	14.07 **	563.88 **	596.53 **
LSD (5%)	1.907	0.218	1.807	2.036		0.135	0.006	0.107	0.704
LSD (1%)	2.712	0.310	2.712	2.962		0.192	0.009	0.152	1.001

1967

0	1.99	.220	4.37		(57.56)	7.98	.208	16.62	28.9
0	5.07	.212	10.73	10.0	(83.72)	12.53	.188	23.59	28.2
0	5.23	.221	11.56	22.1	(109.88)	13.20	.193	25.54	23.2
0	6.71	.184	12.37	15.8	(136.04)	14.40	.208	28.93	21.3
0	7.15	.174	12.45	11.9	(162.20)	16.18	.189	30.65	18.9
0	7.15	.170	12.12	9.3	(188.36)	14.15	.215	30.41	16.1
F Value	71.853 **	12.67 **	363.8 **	1303.67 **		80.881 **	33.35 **	93.291 **	112.71 **
LSD (5%)	0.62	0.020	0.162	1.127		0.300	0.062	5.636	1.503
LSD (1%)	0.88	0.029	0.230	1.640		0.427	0.089	8.017	2.139

Total 1965–67

0	4.34	.174	7.57		(57.56)	13.10	.193	25.32	44.0
26.16	12.94	.168	21.69	82.9	(83.72)	25.02	.180	45.04	53.8
52.32	14.92	.174	26.03	49.8	(109.88)	27.87	.187	52.04	47.4
78.48	18.00	.172	30.94	39.4	(136.04)	31.64	.190	60.18	44.2
104.64	19.41	.168	32.52	31.1	(162.20)	34.43	.191	65.92	40.6
130.80	19.70	.174	34.30	26.2	(188.36)	33.97	.192	65.11	34.6

Table 6. Effects of rates of fertilizer phosphorus on ladino clover-orchardgrass pasture mixture, dry matter (ton/ha), and P uptake (% of applied P).

1965

Applied P kg/ha	Dry matter	% P	kg P	% applied P uptake	Applied P kg/ha	Dry matter	% P	kg P	% applied P uptake
0	1.89	.174	3.29		0	1.89	.174	3.29	
26.16	5.64	.121	6.80	26.0	26.16	5.64	.121	6.80	26.0
52.32	6.54	.211	13.80	26.4	52.32	6.54	.211	13.80	26.4
78.48	7.08	.217	15.37	19.6	78.48	7.08	.217	15.37	19.6
104.64	7.66	.245	18.77	17.9	104.64	7.66	.245	18.77	17.9
130.80	8.22	.230	18.91	14.9	130.80	8.22	.230	18.91	14.9
F Value	2568.72 **	206.67 **	10350.83 **	350.46 **					
LSD (5%)	0.14	0.01	0.20	1.63					
LSD (1%)	0.20	0.05	0.28	2.30					

1966

	Not topdressed					Topdressed			
0	1.54	.242	3.72		(28.78)	5.09	.228	11.59	40.3
0	5.37	.132	7.10	27.3	(54.94)	9.63	.241	23.20	42.2
0	6.34	.209	13.23	25.3	(81.10)	10.46	.231	24.12	29.7
0	6.54	.218	14.23	18.1	(107.26)	10.90	.230	24.92	23.2
0	7.68	.186	14.26	13.6	(133.42)	11.08	.230	25.50	19.1
0	8.30	.190	15.76	12.0	(159.58)	12.81	.217	27.74	17.4
F Value	2579.04 **	73.33 **	4218.82 **	740.94 **		20.56 **	5.33 *	1182.26 **	466.95 **
LSD (5%)	0.15	0.01	0.23	0.79		0.35	0.01	0.52	1.55
LSD (1%)	0.21	0.02	0.33	1.13		0.50	0.01	0.74	2.21

1967

0	2.44	.211	5.16		(57.56)	8.79	.209	18.39	31.9
0	2.79	.194	5.40	20.6	(83.72)	10.14	.214	21.71	25.9
0	5.97	.198	11.83	22.6	(109.88)	10.18	.228	23.26	21.2
	7.01	.186	13.02	16.6	(136.04)	10.78	.223	24.07	17.7
0	7.21	.182	13.11	12.5	(162.20)	11.64	.222	25.85	15.9
0	7.66	.192	14.71	11.2	(188.36)	11.83	.238	28.21	15.0
F Value	1082.69 **	7.50 **	1761.06 **	208.64 **		201.54 **	7.11 **	2753.54 **	445.52 **
LSD (5%)	0.22	0.01	0.31	1.08		0.25	0.01	0.20	0.98
LSD (1%)	0.32	0.02	0.45	1.53		0.35	0.02	0.29	1.39

Total 1965-67

0	5.87	.207	12.16		(57.56)	15.77	.211	33.27	57.8
(26.16)	13.80	.140	19.29	73.7	(83.72)	25.41	.204	51.71	61.8
(52.32)	18.85	.206	38.86	74.2	(109.88)	27.18	.225	61.17	55.7
(78.48)	20.63	.207	42.62	54.3	(136.04)	28.76	.224	64.37	47.3
(104.64)	22.55	.205	46.13	44.3	(162.20)	30.38	.231	70.12	43.2
(130.80)	24.18	.204	49.38	37.8	(188.36)	32.86	.228	74.86	39.8
F Value									
LSD (5%)									
LSD (1%)									

on this soil—very low in available P, and high in P fixing capacity.

Pasture type. Ladino clover-orchardgrass dry matter yields were increased each year by each initial increment of applied fertilizer phosphate (Table 6). In the seeding year and in 1966, the lowest increment, 26.16 kg P/ha (300 kg superphosphate) stimulated growth but the percent P, .121 and .132, respectively, in 1965 and 1966, were much too low for livestock forage. In 1967 the ladino clover-orchardgrass yield with 26.16 kg/ha of P dropped to about half of the 1966 yield. Since the removal of 13.9 kg P/ha (6.8 and 7.1 kg/ha, respectively, in 1965 and 1966) amounted to half the application of 26.16, this large yield decrease may have resulted from inadequate available P.

Topdressing effects. Topdressing in 1966 increased yields of hay mixture 75 to 90 percent and in 1967, 100 to 150 percent (Table 5). Pasture mixture yields were increased 45 to 75 percent in 1966 and 55 to 70 percent in 1967 by the annual topdressing of 36, 28.8 and 55 kg/ha of N, P, K, respectively (Table 6). In addition to increased dry matter, topdressing increased the percent P in the forage.

Dry matter yields of orchardgrass in the pasture mixture and timothy in the hay, even when growing in association with legumes, would be expected to be increased by the annual topdress application of 36 kg N/ha. On many sandy loam soils, the annual topdressing of fertilizer K would increase dry matter yields of both the grass and the legume—timothy and red clover in the hay mixture and ladino clover and orchardgrass in the pasture. Thus, the annual topdressing with N, P, K (6–11–11) makes it difficult to evaluate the yield response to annual P topdressings. One can state that even with annual topdress applications of P it is evident that percent P and the dry matter of both hay and pasture mixtures were, in general, increased by each increment of fertilizer P supplied initially at the time of seeding (Tables 5 and 6).

Phosphorus recovery. Phosphorus removed in the forage was compared to increments of fartilizer P supplied initially and initial plus topdressing. This was expressed as percent of P taken up (Tables 3 and 4). The hay mixture of red clover-timothy removed large quantities of P in 1966 and 1967. With the hay mixture, the lowest initial increment of P (26.16) resulted in removal of 21.7 kg P/ha or 83 percent. Fifty percent of the P was removed from the second increment. The application of topdressings of fertilizer P which were considered liberal resulted in stimulating yields and plant removal of P in excess of 50 percent of the lowest initial P increment. The pasture mixture ladino clover-orchardgrass removed larger amounts of P than the hay mixture (Tables 3 and 4). The relative plant removal of pasture mixture was 74, 74 and 54 percent of the 26.16, 52.32 and 78.48 kg P/ha, respectively. The topdressing resulted in plant P removal of 44 to 62 percent of the amount of applied fertilizer P. These plant P removal values are in close agreement with values reported by OOHARA *et al.* (2) for alfalfa-orchardgrass and ladino clover-orchardgrass in a 4-year period at

Obihiro, in which all fertilizer P was supplied in precision bands at seeding—none as a topdressing. The annual topdressing of 22 kg P/ha on plots receiving 22 kg of banded P at seeding time at Obihiro did not produce appreciable increases in yield, percent P composition, or P uptake by either the alfalfa-orchardgrass or ladino clover-orchardgrass mixtures (2), indicating high availability of banded P.

Because of the possible effects of topdressed N and K on increased dry matter, the effect of topdressed P is questionable.

The topdressed plots with N–P–K produced plant P removal ranging from 45 to 65 kg/ha for the hay mixture and 52 to 75 for the pasture mixture indicating that the highest initial rate of 130 kg/ha of broadcast fertilizer P might be inadequate to maintain desired percent P in forage and to avoid depletion of soil P when rates of 36 kg N and 55 kg K are topdressed.

Potassium uptake. The capacity of this soil to supply K to both the hay and the pasture mixtures was unusually large (Table 7).

In the seeding year, the hay mixture removed amounts of K ranging from 1.3 to 2 times the 72 kg K/ha supplied initially.

Potassium removal by the pasture mixture the first year was 3 to 4 times that initially applied as fertilizer K. Total K removal in the seeding plus two

Table 7. Potassium content and uptake by forage.

Applied P	Hay mixture 1965 % K	Hay mixture 1965 kg K	Hay mixture 1965–67 % K	Hay mixture 1965–67 kg K	Hay mixture 1965–67 % applied	Pasture mixture 1965 % K	Pasture mixture 1965 kg K	Pasture mixture 1965–67 % K	Pasture mixture 1965–67 kg K	Pasture mixture 1965–67 % applied
Not topdressed										
0	3.45	33.8	2.61	113.3	157	4.10	77.5	3.14	184.2	256
26.16	3.25	93.8	3.11	340.3	473	4.54	256.1	2.97	410.5	570
52.32	3.50	111.3	2.73	407.7	566	4.12	270.0	3.27	616.5	856
78.48	3.17	114.2	2.69	483.5	672	3.99	282.5	3.13	646.1	897
104.64	3.36	138.8	2.61	508.9	707	3.93	300.8	3.08	695.5	966
130.80	3.40	148.0	2.59	510.1	708	3.83	314.7	3.15	762.3	1059
K applied		72		72			72		72	
Topdressed kg/ha 36 N 28.8 P 55 K in 1966, 1967										
0			2.45	320.5	176			2.86	451.8	248
26.16			2.41	602.9	331			3.46	787.9	433
52.32			2.60	725.0	398			3.04	825.5	454
78.48			2.52	798.1	439			3.06	880.3	484
104.64			2.67	928.1	510			3.12	946.1	520
130.80			2.62	889.0	488			3.10	1017.8	559
K applied				182					182	

harvest years was, for hay mixture 5 to 7, and for pasture mixture 6 to 10 times the initial application.

When 55 kg of K was applied annually as a topdressing, K removal was for hay 3 to 5, and for pasture 4 to 5.5 times the K supplied.

Chemical composition of the hay mixture was 2.3 to 2.6 percent K in 1966 and 2.4 to 2.65 in 1967, and for pasture, 2.3 to 2.7 in 1966 and 2.9 to 3.0 in 1967. Minimum values of 3.5 percent K for ladino clover and 3.5 to 4.0 for associated orchardgrass are indicated for sustained high perennial yields of ladino clover-orchardgrass and only slightly lower K values are required for sustained high yields of red clover-timothy hay mixtures. Thus, even on this soil with high capacity to supply K, the annual K topdressing of 55 kg/ha was too small.

Nitrogen uptake. Nitrogen of 63 kg/ha were applied as basic fertilizer and 36 kg N were topdressed in the topdressed plots from the following year. The hay mixture removed amounts of N ranging from 2 to 7,3 times and the pasture mixture was 2.6–10.8 times respectively in the non-topdressed plots, although their amounts varied according to the increase of P application.

The topdressed plots of K removed more N 2.5–5.8 times in the hay mixture and 3.2–7.1 times in the pasture type. As mentioned above, the application of P and the topdressing of K made nitrogen uptake heavy (Table 8.)

Table 8. Nitrogen content and uptake by forage

Not topdreesed

Applied P	Hay mixture					Pasture mixture				
	1965		1965–67			1965		1965–67		
	% N	kg N	% N	kg N	% applied	% N	kg N	% N	kg N	% applied
0	3.73	36.59	3.02	127.27	202	2.90	55.98	2.87	165.39	263
26.16	2.34	67.74	2.34	304.11	483	2.81	164.31	2.76	323.69	514
52.32	2.94	93.40	2.82	378.30	600	2.90	196.78	2.90	539.22	856
78.48	2.04	73.26	2.23	405.06	643	2.74	205.09	2.87	580.45	921
104.64	2.07	85.57	2.26	441.92	701	2.91	234.36	2.87	620.92	986
130.80	2.47	108.06	2.39	460.12	730	3.14	274.48	2.90	683.15	1084
N applied		63		63			63		63	
Topdressed kg/ha 36 N 28.8 P 55 K in 1966, 1967										
0			2.15	340.82	252			2.88	430.68	319
26.16			2.44	617.71	458			2.87	719.02	533
52.32			2.62	649.24	481			2.91	778.32	577
78.48			2.36	740.39	548			2.82	784.31	581
104.64			2.30	843.87	625			2.96	873.97	647
130.80			2.32	781.01	579			3.04	958.08	710
N applied				135					135	

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Summary

Hay mixture of red clover-timothy and pasture mixture of ladino clover-orchardgrass were grown on sandy loam soil of volcanic ash origin with initial increments of P ranging from 26 to 130 kg/ha.

Annual topdressing with 36 kg N, 28.8 kg P and 55 kg K increased hay mixture dry matter yields 75 to 90% in 1966 and 100 to 150% in 1967 and increased pasture mixture yields 45 to 75% in 1966 and 55 to 70% in 1967. Even with annual topdressing of 28.8kg P, percent P and dry matter yields of both hay and pasture mixtures were increased by each increment of initially applied P. This points to the great value of supplying liberal amounts of fertilizer P preferably in bands before seeding.

Potassium removed by the hay mixture was 3 to 5 times greater for hay mixture and 4 to 5.5 times greater than the 182 kg K supplied.

This stresses the tremendous requirement for annually applied topdressing of fertilizer K to meet requirements for sustained high yields of perennial forage.

Nitrogen removed by the hay mixture was 2 to 7 times and 2 to 10 times by the pasture mixture respectively depending on the increase of phosphorous application and potassium topdressing.

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摘　　要

1965～1967年の3カ年にわたり，火山灰草地の採草型（アカクローバー・チモシー混播）と放牧型（ラデノクローバー・オーチャードグラス混播）植生における燐酸施用量をヘクタール当り26～130 kg (Pとして) を基肥とし，追肥は年々ヘクタール当り 36 kg N, 28.8 kg P および 55 kg Kを施用し，その収量および養分吸収におよぼす影響についての研究を実施した。その結果によると採草型では1966年に75～90%，1967年に100～150%の増収，放牧型では1966年に45～75%，1967年に55～70%の増収が示された。基肥としてのPと28.8 kg Pの追肥によっても両混播の乾物生産はもとより，P含量および吸収量は増加したが，Pの吸収率は低下した。K追肥の効果は大きく，採草型では施用したKの3～5倍，放牧型で4～5.5倍の量を吸収した。このように永年生牧草混播において高収量をあげるためにはかなり多い加里追肥を行なうべきであろう。

窒素も燐酸および加里の施用量が増加するとともに多量の収奪が行なわれ，施用窒素に対して採草型では2～7倍，放牧型では2～10倍の窒素が混播牧草によって吸収されている。