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The Effects of Fertilizer Phosphorus and Potassium on Yield and Composition of Alfalfa-Orchardgrass and Ladino Clover-Orchardgrass Mixture for the Second Five-Year Period

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基肥としての燐酸および加里追肥が生育 6–10 年次 (1965–1969) におけるアルファルファ・オーチヤードグラスおよびラデノクローバ・オーチヤードグラス混播の乾物生産，N・P および K 含量に及ぼす影響

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Japan has a strong national program to improve the protein level of human foods. Dairy products are a major expandable source of desirable protein food. The continuing expansion of dairy cattle numbers greatly increases the demand for high quality cattle feed, especially that produced by improved forage legumes and grasses. There has also been an increasing awareness of the importance of fertilizers in the production and maintenance of stands of improved varieties and strains of perennial forage plants.

The Forage Research Center at Obihiro Zootechnical University, has carried out a number of experiments on the fertility requirements of some of the more recently introduced perennial legume and grass forage plants. This report is a part of these studies.

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PLANT NUTRIENT PHOSPHORUS

Phosphorus (P) is considered one of the most important mineral nutrients in the seedling stage of forage crop development. The amount and placement of fertilizer P are often critical to forage seedling establishment, especially so on (1) soils low to medium in available P; (2) soils with a high P-fixing capacity; and (3) soils subject to drought or cold damage. Seeds of perennial legumes and grasses are relatively small, containing minute amounts of phosphorus as compared to seeds of most cultivated plants (cereals, beans, etc.). Phosphorus is an essential part of amino acids and protein and is required in the energy cycle of plants. Thus, an abundance of soluble phosphate placed near the seed to intercept the emerging secondary roots is required for rapid initial development of the seedling. This rapid initial development provides a greater root system to exploit soil moisture and nutrients, and aids in reducing drought injury. Also, rapid seedling development increases the young forage plants' ability to compete with weeds, for mineral nutrients, moisture and light.

Fertilizer phosphorus should be applied before seeding. The P amounts applied should equal the expected P removed in forage crops during the 3 to 5 year productive life of the legume-grass mixture. Research has demonstrated that greatest P efficiency is achieved by placing the P fertilizer in undisturbed bands 6–8 cm below the soil surface and drilling the seed directly above the P fertilizer bands. Banding P reduces contact between the seed and fertilizer, thus reduces P fixation by active soil aluminum and iron. The developing seedling roots rapidly intercept the P fertilizer band or the zone of high soluble P near the band, thereby obtaining the abundance of P required for rapid development.

Once established, the roots of perennial legumes and grasses utilize P from relatively insoluble sources such as variscite $Al(OH)_2$ H_2PO_4, strengite $Fe(OH)_2$ H_2PO_4, ground rock phosphate, etc. Annual topdressings of soluble phosphate fertilizers are highly inefficient in increasing perennial forage crop yields. Soluble P is rapidly fixed and remains at the soil surface, relatively unavailable to plant roots. Hence, banding enough soluble P at seeding to equal crop removal for 3 to 5 years is recommended.

PLANT NUTRIENT POTASSIUM

Potassium (K) has several essential roles in plant metabolism: protein formation; formation and translocation of carbohydrates within the plant; enzyme regulation of plant processes as respiration; formation of organic acids and oils; favorable cell pressure and regulation of stomata influencing water economy and

gas exchange in plant leaves. The level of K in the cell sap directly and indirectly affects cold resistance.

Adequate levels of K are required during seedling development to establish vigorous stands of perennial legumes and grasses. However, K most often limits the vigor, duration, and yields after the seedling year. Many investigators have shown that annual applications of liberal amounts of K are required to sustain the productivity and longevity of superior forage legume-grass mixtures. Parsons (8) during 3 crop years applied fertilizer K totalling 540, 460 and 375 kg/ha of K as KCl, respectively, to orchardgrass, smooth bromegrass and timothy grown on a fine sandy loam. The forage harvested from these orchardgrass, smooth bromegrass and timothy plots contained 94, 87 and 79%, respectively, of the fertilizer K applied, demonstrating that on sandy loam soil it was not possible to increase soil K reserves when producing large yields of forage. Weedy species competition for K greatly reduced stands of grasses and legumes at low levels of soil K (8).

Materials and Methods

The soil, derived from volcanic ash, contained about 10% organic matter, has a pH 6.0 surface and 6.5 subsurface, and was deficient in available nitrogen, phosphorus, potassium and magnesium. The climate is characterized by short, cool, moist summers of 120–140 frost free days, and long cold winters. Snow cover may exceed 120 days, and annual precipitation ranges from 850–1000 mm with excellent distribution in June, July and August. The climate is similar to that of Portland, Maine, U.S.A.

On May 9, 1960, two blocks, (a) Du Puits alfalfa (5 kg/ha), and Massachusetts Hardy orchardgrass (4 kg/ha) and (b) Ladino clover (1 kg/ha), with Massachusetts Hardy orchardgrass were precision drilled directly over bands of 11–21–0 (N–P–K) [11–48–0, N–P_2O_5–K_2O] placed 6–8 cm deep and supplying 0, 22, 44 and 88 kg P/ha (0, 50, 100, 200kg P_2O_5/ha). A uniform soil treatment of dolomitic limestone at the rate of 5000 kg; potassium chloride (200 kg); urea (100 kg); and fertilizer borax (25 kg) were broadcast and disked into the surface 6 inches before applying the P fertilizer bands. [See five year effects of fertilizer phosphorus and potassium on yield and composition of alfalfa-orchardgrass and Ladino clover-orchardgrass mixtures (1960–1964), (2)].

The first five year period had two levels of K, 0 and 83 kg K/ha after each of 3 cuttings annually (250 kg K or 300 kg K_2O supplied as KCl). The second five year period had three levels of K, 0, 83 and 167 kg K/ha after each of 3 cuttings annually (0, 250, 500 kg K/ha supplied as KCl).

Cutting data:

No. of cut	1965	1966	1967	1968	1969
1	June, 15	June, 22	June, 9	June, 18	June, 17
2	Aug., 6	Aug., 13	July, 26	Aug., 2	Aug., 18
3	Sept., 14	Sept., 22	Sept., 23	Oct., 11	Sept., 27

Plot design:

Block		Basic application of P in the first year-1960		Topdressing of K (no, med., heavy)		Numbers of replication
2	×	4	×	3	×	3

(AL−OG, LC−OG) =72 plots

Summary of Results 1960–1964

Excellent forage yields were produced in the four harvest years 1961–64. Alfalfa-orchardgrass averaged above 32,000 kg/ha of dry matter (4 tons/acre annually) and 30,000 kg/ha (3.5 tons acre) for Ladino clover-orchardgrass. The first increment of fertilizer P (22 kg P/ha) produced 11% increases for both legume-grass mixtures (2).

In the seeding year (1960) there were two harvests of each legume-grass mixture. Alfalfa yields were increased fivefold and Ladino clover threefold by fertilizer P in the first cutting. While alfalfa yields were increased greatly in each harvest by increments of fertilizer P, %P in the forage increased at 44 and 88 kg P/ha rates. Orchardgrass responded to the first increment of P in the first cutting, but was depressed in the second, probably by the increased competition of the vigorous alfalfa growth response. In the first harvest Ladino clover yields increased 60, 90 and 200%, respectively, for 22, 44 and 88 kg P/ha but only at the 88 kg P/ha rate in the second cutting of 1960. Annual topdress applications of fertilizer P were relatively ineffective in stimulating increases in yield or P composition.

While yields of both alfalfa and Ladino clover were greatly increased by fertilizer P in the seedling year, yield increases produced by K for alfalfa and Ladino clover were small the first year, but increased year by year. For example, K induced increases for alfalfa were 7, 45, 128, 428% and for Ladino clover were 17, 101, 157 and 274%, respectively, for the first, second, third and fourth years. Neither P nor K increased the yields of orchardgrass growing in association with alfalfa. Vigorous development of alfalfa competing for light, moisture and mineral nutrients, probably suppressed orchardgrass development. Yields of orchardgrass grown in association with Ladino clover, were increased by potassium fertilizer, as there was less competition from Ladino clover as compared to alfalfa.

During this first five year period, larger amounts of K were removed by both the alfalfa and Ladino clover-orchardgrass mixtures, than was supplied by 83 kg K/ha after each cutting (250 kg K/ha annually). Potassium removal was high in the seedling year 1960 (80 to 110 per cent of applied K), and in the first and second harvest years 1961–1962. Per cent K in alfalfa and Ladino clover were respectively, 2.64 and 2.11 in 1961, but decreased abruptly to 1.95 and 1.27 in 1962 for plots without annual K fertilizer. These reductions in K composition of alfalfa and Ladino clover were associated with yield reductions of 17 and 35 per cent, respectively, for alfalfa and Ladino clover in 1962 and 48 and 59 per cent reductlons, respectively, for alfalfa and Ladino clover in 1963.

Based on this research and on works of others, the following minimum composition values were suggested for sustaining high yields of alfalfa and Ladino clover grown in association with orchardgrass (2). Ladino clover, 3.5; alfalfa, 3.0 to 3.5; and associated orchardgrass, 3.5 to 4.0 per cent K. Supplying 83 kg K after each cutting was not adequate either to balance K removed by these legume-grass forage mixtures or to maintain the desired level of K in the forage plants.

Results of Second Five Year Period, 1965–1969

Growth and dry matter production

The stem heights of forage species as an indicator of plant growth are shown

Table 1. Average plant height (cm) of alfalfa and orchardgrass in the mixture during 1965–1969

Year	Treatment K topdressed (kg/ha)	1st cut		2nd cut		3rd cut	
		AL	OG	AL	OG	AL	OG
1965	no	47.5±3.0	60.0±0.8	67.8±0.5	42.0±0.8	49.3±1.0	48.3±1.9
	250	66.8±1.0	80.5±0.6	85.3±0.5	68.3±1.0	60.0±0.8	61.8±0.5
	500	66.5±0.6	80.0±0.8	86.5±0.6	68.8±0.5	60.5±0.6	62.0±0.0
1966	no	52.5±0.6	69.3±0.5	44.0±0.8	48.0±0.0	40.5±0.6	43.8±0.5
	250	75.8±1.0	85.8±0.5	74.8±0.5	78.3±0.5	57.8±0.5	64.3±0.5
	500	76.8±0.5	88.0±0.8	75.5±0.6	79.3±0.5	59.3±1.0	66.5±0.6
1967	no	54.0±0.8	69.3±1.0	73.8±0.5	51.5±0.6	44.0±0.8	46.8±0.5
	250	81.8±0.5	90.5±0.6	100.2±0.5	76.5±1.7	67.5±0.6	66.8±1.0
	500	81.5±0.6	92.0±0.8	101.0±0.8	76.0±0.0	67.5±0.6	69.0±0.8
1968	no	46.5±1.3	67.0±0.8	50.0±0.8	35.0±0.8	50.5±1.3	38.0±0.8
	250	85.3±1.0	101.3±1.5	77.3±1.0	57.5±1.3	61.5±0.9	51.0±0.9
	500	85.0±0.8	102.5±0.6	78.0±0.8	57.5±0.6	62.3±0.5	52.5±0.6
1969	no	46.8±1.7	58.3±1.3	79.8±1.3	49.8±1.0	36.0±0.8	28.5±0.6
	250	63.0±0.8	72.5±1.3	97.8±1.0	76.8±1.0	58.5±1.3	48.8±1.0
	500	64.0±0.8	75.0±0.8	99.0±0.8	77.8±0.5	59.3±1.0	51.3±1.0

Remarks: AL=alfalfa OG=orchardgrass

Table 2. Average plant height (cm) of Ladino clover and orchardgrass in the mixture during 1965-1969

Year	Treatment K topdressed (kg/ha)	1st cut		2nd cut		3rd cut	
		AL	OG	AL	OG	AL	OG
1965	no	26.5±1.3	58.0±1.4	27.5±0.6	41.5±1.0	20.3±0.5	48.8±1.0
	250	37.3±1.0	80.5±1.3	42.0±0.8	67.0±1.2	33.3±1.0	63.3±1.0
	500	37.5±0.6	80.8±0.5	42.8±1.0	68.3±0.5	35.3±0.5	63.3±0.5
1966	no	25.8±0.5	62.8±0.5	28.5±0.6	48.5±0.5	20.5±0.6	45.5±0.6
	250	38.5±0.6	86.8±0.5	39.5±0.6	78.3±0.5	30.5±0.6	64.5±0.6
	500	38.8±0.5	89.0±0.8	39.5±0.6	79.0±0.0	31.3±0.5	65.3±1.0
1967	no	29.8±0.5	75.5±0.6	29.0±0.8	51.5±0.6	27.5±0.6	48.0±0.8
	250	40.5±0.6	92.5±0.6	37.8±0.5	76.8±1.0	31.8±0.5	67.8±0.5
	500	41.8±0.5	92.0±0.8	38.8±0.5	78.3±0.5	31.8±0.5	68.5±0.6
1968	no	23.3±0.5	81.0±0.8	26.8±0.5	39.5±1.3	22.3±1.0	42.3±0.5
	250	38.5±1.3	103.5±0.6	44.5±0.6	61.3±1.0	28.8±4.6	53.5±0.6
	500	39.0±0.8	104.0±0.8	43.0±0.8	62.8±1.0	32.0±0.8	54.3±0.5
1969	no	22.3±1.0	58.8±0.5	21.5±0.6	53.0±0.8	16.8±0.5	30.8±1.0
	250	32.5±1.3	72.3±1.0	34.0±0.8	80.5±1.3	28.8±1.0	48.8±0.5
	500	33.0±0.8	76.0±0.8	35.0±0.8	80.8±1.0	30.0±0.8	48.8±0.5

in Tables 1 and 2.

a. Alfalfa-orchardgrass block

The stem heights of both forages varied by year, topdressing of K, kinds of species and cutting stage. The stem height of orchardgrass at the first cutting was higher than that of alfalfa and the stem heights of both species at the third cutting were nearly the same. A particularly outstanding effect on the stem height appeared with the topdressing of K, resulting in plants about 20 cm taller than those in not using topdressing of K.

b. Ladino clover-orchardgrass block

The general tendencies appearing in the Ladino clover-orchardgrass block were almost the same as these in the alfalfa-orchardgrass block. The stem heights of both species had a close correspondence to the topdressing of K.

The yield of dry matter in the mixture and the rate of legume to total dry matter are indicated in Tables 3 and 4.

a. Alfalfa-orchardgrass block

The dry matter in the mixture increased notably by the topdressing of K. The yearly variation between forages and the cutting stage also appeared.

Total dry matter in 1967, when temperatures in May, July and August were higher and rainfall in June and July was greater than in 1965, 1966, 1968 and

1969 was highest when compared to that in other harvest years.

The rate of dry matter of alfalfa compared to the total dry matter in the mixture became remarkably higher through the topdressing of K. This means that alfalfa was more responsive to the K application than orchardgrass.

b. Ladino clover-orchardgrass block

Table 3. Yield of dry matter (kg/ha) and the rate (%) of alfalfa to total dry matter in alfalfa-orchardgrass mixture

Treatment K top-dressing (kg/ha)	Year	1st cut				2nd cut			
		AL	OG	Total	Ratio of AL	AL	OG	Total	Ratio of AL
no K	1965	48± 19	1085±165	1133±178	4.16±1.47	115±33	1200± 47	1315± 21	8.75±2.61
	1966	87± 5	948± 33	1035± 37	8.58±0.30	138±15	1025± 38	1163± 35	11.8 ±1.35
	1967	112± 38	2023± 21	2135± 44	5.28±1.68	148±28	1060±113	1208±133	12.05±1.44
	1968	80± 18	1460± 75	1540± 67	5.25±1.26	70± 8	1013± 47	1083± 48	6.33±0.76
	1969	108± 28	970± 43	1078± 67	9.63±1.99	117±36	1593± 54	1700± 86	6.90±1.72
250	1965	910± 63	1818±173	2728±165	33.43±2.79	1067± 97	1953±104	3020± 8	35.41±3.31
	1966	815± 31	1783± 71	2598± 67	31.05±1.36	1090± 39	1785± 80	2875± 42	37.90±1.70
	1967	1307± 46	3083± 83	4390± 57	29.83±1.23	1118± 39	1520±102	2638± 74	42.21±2.38
	1968	1980± 63	1603±217	3583±197	55.38±3.74	1800± 74	1468± 50	3268± 61	55.02±1.64
	1969	1197±156	998±148	2195± 58	54.55±6.75	1270± 88	1700± 57	2970± 71	42.81±2.27
500	1965	862± 25	1893± 69	2755± 79	31.28±0.90	1100± 50	2088± 47	3188± 73	34.55±1.08
	1966	905± 29	1798± 54	2703± 26	33.48±1.38	1205± 39	2045± 40	3250± 28	37.25±1.63
	1967	1262± 53	3053± 61	4315± 26	29.25±1.26	1043± 46	1565± 68	2608± 33	40.00±2.05
	1968	1917±121	1523±111	3440±126	55.75±2.80	1757± 46	1528± 57	3285± 57	53.50±1.33
	1969	1535±110	803± 57	2338± 54	65.58±3.15	1433± 83	1865± 51	3298± 70	43.42±1.91

Treatment K top-dressing (kg/ha)	Year	3rd cut				Total			
		AL	OG	Total	Ratio of AL	AL	OG	Total	Ratio of AL
no K	1965	47± 10	838± 39	885± 30	5.33±1.25	210± 56	3122± 82	3332±136	6.25±1.47
	1966	42± 5	713± 13	755± 13	5.65±0.64	268± 10	2685± 48	2953± 39	9.05±0.44
	1967	115± 19	1000± 54	1115± 71	10.33±1.08	375± 51	4083± 88	4458± 97	8.43±1.08
	1968	25± 6	578± 43	603± 38	4.00±1.20	175± 24	3050±128	3225±112	4.73±0.88
	1969	33± 10	675± 52	708± 55	4.80±1.32	257± 64	3228±133	3485±193	7.35±1.39
250	1965	445± 5	940± 5	1385± 5	32.23±0.37	2422±111	4710±214	7133±168	33.95±1.89
	1966	575± 13	1340± 35	1915± 37	30.12±0.72	2480± 43	4683±105	7388± 85	33.58±0.78
	1967	630± 36	1325± 56	1955± 53	32.14±1.74	3055±102	5928±192	8983±112	34.03±1.43
	1968	807± 51	1313±112	2120±112	38.24±2.69	4588± 79	4382±207	8970±248	51.15±1.13
	1969	1170± 83	1010± 51	2230± 57	54.61±2.74	3687±241	3708±216	7395±121	49.85±2.99
500	1965	480± 22	958± 22	1438± 26	33.45±1.23	2442± 30	4938± 82	7380± 55	33.12±0.63
	1966	590± 32	1430± 56	2020± 37	29.20±1.82	2700± 41	5273± 69	7973± 68	33.88±0.51
	1967	625± 13	1333± 50	1958± 53	32.03±0.87	2930± 73	5950± 71	8880± 48	33.01±0.77
	1968	715± 70	1437± 52	2153±111	33.20±1.73	4390±160	4488± 62	8878±195	49.43±0.82
	1969	1290± 61	1085± 62	2375± 13	54.35±2.58	4257±172	3753±100	8010±101	53.15±1.61

Table 4. Yield of dry matter (kg/ha) and the rate (%) of Ladino clover to total dry matter in Ladino clover-orchardgrass mixture

Treatment K top-dressing (kg/ha)	Year	1st cut				2nd cut			
		LC	OG	Total	Ratio of LC	LC	OG	Total	Ratio of LC
no K	1965	163± 43	865±178	1028±193	16.12±4.10	70± 12	1155± 58	1225± 48	5.83±1.14
	1966	150± 22	953± 32	1103± 49	13.63±1.52	208± 15	1105± 44	1313± 41	15.98±1.29
	1967	238± 21	2560± 32	2798± 42	8.48±0.66	263± 26	1260± 47	1523± 69	17.05±1.07
	1968	125± 13	1138± 77	1263± 90	9.93±0.38	207± 40	1203± 21	1410± 59	14.58±2.26
	1969	165± 24	915± 25	1080± 29	15.15±2.04	87± 15	1583± 46	1670± 55	5.30±0.79
250	1965	785± 62	1548± 72	2333± 85	33.63±2.26	935± 37	1910± 34	2845± 34	32.83±1.12
	1966	880± 57	1648± 43	2528± 35	34.78±1.96	1165± 22	1810± 51	2975± 36	39.00±1.06
	1967	1008± 49	3930± 22	4938± 49	20.35±0.79	667± 51	1788± 68	2455± 62	26.45±2.03
	1968	753± 71	3255±223	4008±267	18.78±1.31	1600± 28	1825± 83	3425± 73	46.75±1.42
	1969	600± 56	1350± 33	1950± 48	30.70±2.28	1030± 43	1780± 88	2810±112	36.65±1.14
500	1965	853± 36	1730±104	2583±133	33.08±0.90	965± 60	1975± 90	2940± 62	32.85±2.20
	1966	940± 24	1653± 17	2593± 19	36.25±0.78	1197± 51	1838± 42	3035± 21	39.50±1.55
	1967	995± 40	3968± 26	4963± 26	20.08±0.71	662± 26	1803± 76	2465± 50	26.90±1.62
	1968	660± 72	3513± 99	4173±108	15.80±1.55	1478± 35	2008± 83	3495± 87	42.63±1.21
	1969	570± 24	1420± 80	1990± 65	28.68±2.11	1120± 58	1995± 68	3115± 83	35.95±1.52

Treatment K top-dressing (kg/ha)	Year	3rd cut				Total			
		LC	OG	Total	Ratio of LC	LC	OG	Total	Ratio of LC
no K	1965	53± 5	850± 58	903± 58	6.23±0.66	285± 40	2870±256	3155±267	9.05±1.27
	1966	30± 0	725± 13	755± 13	3.90±0.07	387± 13	2783± 65	3170± 55	12.23±0.68
	1967	75± 6	1037± 10	1088± 13	7.21±0.47	575± 25	4833± 71	5408± 96	10.60±0.28
	1968	42± 5	1013± 29	1055± 33	3.90±0.35	375± 57	3353±107	3728±162	10.03±1.10
	1969	60± 8	728± 30	788± 33	7.65±0.91	313± 24	3225± 42	3538± 49	8.83±0.62
250	1965	345± 13	823± 25	1168± 22	29.35±1.22	2065± 33	4280±104	6345±124	32.55±0.48
	1966	555± 10	1440± 40	1995± 44	27.78±0.55	2597± 42	4898± 26	7495± 40	34.65±0.43
	1967	433± 15	1580± 54	2013± 51	21.53±0.95	2082± 36	7298± 87	9380± 88	22.20±0.74
	1968	692± 66	1343± 24	2035± 44	34.05±2.52	3045±155	6423±270	9468±354	32.15±1.20
	1969	747± 13	1238± 83	1985± 95	37.68±1.19	2377± 83	4368±140	6745±162	35.28±1.09
500	1965	355± 13	855± 60	1210± 65	29.38±1.38	2173± 26	4560±208	6733±170	32.28±1.19
	1966	565± 17	1478± 22	2043± 30	27.73±0.65	2707± 70	4968± 77	7670± 16	35.23±0.95
	1967	493± 31	1620± 24	2113± 26	23.23±1.30	2150± 35	7390± 67	9540± 32	22.55±0.44
	1968	713± 74	1370± 29	2083± 51	34.10±2.75	2860± 99	6890± 80	9750±139	29.33±0.72
	1969	788± 36	1350± 49	2138± 67	36.78±1.19	2478± 78	4765±174	7243±201	34.23±0.96

Remarks: LC=Laclino clover

The yield of dry matter in the Ladino clover-orchardgrass block became higher with the topdressing of K as compared with the alfalfa-orchardgrass block, but the ratio of dry matter in Ladino clover to total dry matter of the mixture was slightly less when compared to alfalfa. Total dry matter with a topdressing of 250 kg K/ha was not significantly increased with a topdressing of 500 kg

K/ha.

As shown in Tables 3 and 4, the topdressing of K in both mixtures brought a strong response in obtaining a higher tonnage of dry matter, and in increasing the ratio of legume in the mixture. The application of at least 250 kg K/ha seems necessary for getting results such as those reported above.

Phosphorus In contrast to the large yield response to increments of applied fertilizer P in the seedling year, there was no yield response to P increments in this second five year period (Tables 5, 6, 7, 8, and 9). Plants were analyzed for N, P, K in 1965, 1967 and 1969. It is important to note that a serious reduction in P content of forage from all plots occurred in 1969. In 1965 and 1967 the forage ranged from .18 to .21 per cent P in alfalfa and from .19 to .23 for orchardgrass in the alfalfa-orchardgrass mixtures. However, in 1969 alfalfa contained only .13 to .15 per cent P in the first cutting and orchardgrass only .15 to .17. A similar reduction in P content occurred in the Ladino clover-orchardgrass mixtures in 1969. In 1965 and 1967, Ladino clover ranged from .19 to .22 and associated orchardgrass from .18 to .21. However, in the first cutting 1969, Ladino clover ranged from .13 to .15 and associated orchardgrass from .15 to .16. A level of .15 per cent P in hay or pasture is considered deficient for beef cattle. Composition higher than .15 per cent P in hay or pasture forage is desired for dairy cattle. These low P values in the first cutting of 1969 indicate reserves of soil P are being exhausted and that future production may be seriously deficient in P.

As shown in Tables 5 and 6, the phosphorus content of legumes and grass in both mixtures became lower with the advance of the harvest year. Generally it seems that the phosphorus content in legumes was lower than that in orchardgrass. It is considered that the critical value of phosphorus content in forage is .13% for dry matter. This value of .13% or less appeared in alfalfa and Ladino clover in 1969. In average years, the phosphorus content in most legume and grass forages was about .2%.

On examining data in Table 10, even the highest increment of fertilizer P applied at planting has been inadequate to balance the P removal by either alfalfa or Ladino clover-orchardgrass mixtures during the 1960–1969 period. Although 88 kg P/ha was supplied before planting as superphosphate (1000 kg/ha), removal of 164.5 and 163.1 kg P/ha, respectively, by alfalfa-orchardgrass and Ladino clover-orchardgrass mixtures, has seriously depleted soil P reserves.

Potassium Potassium had a profoundly favorable effect in maintaining a desirable ratio of alfalfa to orchardgrass and Ladino clover to orchardgrass as shown in Tables 11, 12, 13, 14 and Figs. 1 and 2. Alfalfa from plots without annual K contributed only 5 to 9 per cent of the alfalfa-orchardgrass yield as contrasted

Table 5. Phosphorus content (% in dry matter) of legume and of grass in alfalfa-orchardgrass mixture as affected by maintenance K fertilizer (kg K/ha)

Year	kg P/ha	No K						250 kg K						500 kg K					
		1st cut		2nd cut		3rd cut		1st cut		2nd cut		3rd cut		1st cut		2nd cut		3rd cut	
		AL	OG	AL	OG	AL	OG	AL	OG	AL	OG	AL	OG	AL	OG	AL	OG	AL	OG
1965	(1) 0	0.18	0.17	0.20	0.21	0.19	0.20	0.18	0.20	0.21	0.21	0.19	0.18	0.20	0.21	0.20	0.21	0.18	0.19
	(2) 22	0.22	0.20	0.20	0.20	0.17	0.20	0.18	0.20	0.21	0.23	0.20	0.18	0.21	0.21	0.21	0.21	0.18	0.20
	(3) 44	0.21	0.21	0.20	0.20	0.20	0.21	0.20	0.19	0.22	0.22	0.20	0.21	0.21	0.21	0.21	0.21	0.20	0.19
	(4) 88	0.20	0.20	0.21	0.22	0.19	0.20	0.21	0.21	0.21	0.23	0.19	0.20	0.21	0.21	0.21	0.21	0.21	0.21
	Average	0.20 ±0.02	0.19 ±0.02	0.20 ±0.00	0.21 ±0.01	0.19 ±0.01	0.20 ±0.00	0.19 ±0.01	0.20 ±0.01	0.21 ±0.00	0.22 ±0.01	0.19 ±0.01	0.19 ±0.01	0.21 ±0.00	0.21 ±0.00	0.21 ±0.00	0.21 ±0.00	0.19 ±0.01	0.20 ±0.01
1967	(1) 0	0.18	0.19	0.20	0.21	0.20	0.18	0.19	0.18	0.20	0.19	0.19	0.20	0.18	0.21	0.20	0.21	0.18	0.20
	(2) 22	0.19	0.19	0.20	0.21	0.21	0.21	0.22	0.21	0.22	0.21	0.22	0.19	0.22	0.22	0.20	0.23	0.21	0.22
	(3) 44	0.21	0.21	0.21	0.21	0.19	0.19	0.21	0.22	0.21	0.22	0.21	0.21	0.22	0.23	0.20	0.22	0.22	0.21
	(4) 88	0.21	0.19	0.22	0.21	0.19	0.21	0.21	0.19	0.23	0.22	0.21	0.19	0.19	0.22	0.20	0.22	0.21	0.19
	Average	0.20 ±0.02	0.19 ±0.01	0.21 ±0.01	0.21 ±0.00	0.20 ±0.01	0.20 ±0.01	0.21 ±0.01	0.20 ±0.02	0.21 ±0.01	0.21 ±0.01	0.21 ±0.01	0.20 ±0.01	0.20 ±0.02	0.22 ±0.01	0.20 ±0.00	0.22 ±0.01	0.20 ±0.02	0.20 ±0.01
1969	(1) 0	0.14	0.16	0.18	0.20	0.17	0.16	0.15	0.16	0.20	0.21	0.18	0.20	0.15	0.18	0.21	0.20	0.20	0.20
	(2) 22	0.12	0.15	0.16	0.17	0.18	0.20	0.15	0.18	0.20	0.23	0.17	0.21	0.17	0.17	0.20	0.22	0.18	0.20
	(3) 44	0.15	0.17	0.17	0.18	0.18	0.18	0.16	0.18	0.18	0.20	0.20	0.20	0.15	0.18	0.20	0.21	0.21	0.21
	(4) 88	0.13	0.17	0.18	0.18	0.18	0.17	0.15	0.18	0.20	0.22	0.20	0.20	0.15	0.18	0.20	0.22	0.18	0.21
	Average	0.13 ±0.01	0.16 ±0.01	0.17 ±0.01	0.18 ±0.01	0.18 ±0.00	0.18 ±0.02	0.15 ±0.00	0.18 ±0.01	0.19 ±0.01	0.21 ±0.01	0.19 ±0.01	0.20 ±0.00	0.15 ±0.01	0.18 ±0.00	0.20 ±0.00	0.22 ±0.00	0.19 ±0.01	0.20 ±0.01

Table 6. Phosphorus content (% in dry matter) of legume and of grass in Ladino clover-orchardgrass mixture as affected by maintenance K fertilizer

Year	kg P/ha	No K						250 kg K						500 kg K					
		1st cut		2nd cut		3rd cut		1st cut		2nd cut		3rd cut		1st cut		2nd cut		3rd cut	
		LC	OG	LC	OG	LC	OG	LC	OG	LC	OG	LC	OG	LC	OG	LC	OG	LC	OG
1965	(1) 0	0.21	0.18	0.18	0.19	0.18	0.20	0.20	0.20	0.20	0.21	0.19	0.21	0.21	0.21	0.20	0.21	0.18	0.18
	(2) 22	0.22	0.21	0.21	0.19	0.21	0.20	0.21	0.20	0.23	0.21	0.22	0.20	0.21	0.22	0.22	0.22	0.21	0.21
	(3) 44	0.21	0.20	0.20	0.21	0.21	0.20	0.21	0.20	0.22	0.21	0.19	0.21	0.22	0.21	0.23	0.22	0.19	0.20
	(4) 88	0.21	0.19	0.20	0.22	0.19	0.19	0.21	0.21	0.22	0.22	0.21	0.21	0.22	0.21	0.23	0.21	0.19	0.21
	Average	0.21 ±0.00	0.19 ±0.01	0.20 ±0.01	0.20 ±0.01	0.20 ±0.01	0.20 ±0.00	0.21 ±0.00	0.20 ±0.00	0.22 ±0.01	0.21 ±0.00	0.20 ±0.01	0.21 ±0.00	0.21 ±0.01	0.21 ±0.00	0.22 ±0.01	0.21 ±0.01	0.19 ±0.01	0.20 ±0.01
1967	(1) 0	0.18	0.21	0.21	0.19	0.20	0.18	0.19	0.19	0.21	0.21	0.18	0.20	0.21	0.19	0.21	0.20	0.20	0.21
	(2) 22	0.21	0.21	0.22	0.19	0.21	0.21	0.19	0.19	0.22	0.21	0.21	0.20	0.21	0.21	0.21	0.22	0.21	0.20
	(3) 44	0.22	0.21	0.21	0.21	0.22	0.22	0.19	0.22	0.22	0.21	0.20	0.22	0.22	0.21	0.22	0.21	0.21	0.22
	(4) 88	0.21	0.22	0.21	0.19	0.20	0.20	0.19	0.22	0.21	0.21	0.21	0.22	0.21	0.21	0.22	0.21	0.21	0.21
	Average	0.20 ±0.02	0.21 ±0.00	0.21 ±0.00	0.19 ±0.01	0.21 ±0.01	0.20 ±0.02	0.19 ±0.00	0.20 ±0.02	0.21 ±0.01	0.21 ±0.00	0.20 ±0.01	0.21 ±0.01	0.21 ±0.00	0.20 ±0.01	0.21 ±0.01	0.21 ±0.01	0.21 ±0.00	0.21 ±0.01
1969	(1) 0	0.15	0.15	0.20	0.17	0.16	0.17	0.16	0.18	0.21	0.20	0.18	0.20	0.17	0.19	0.21	0.21	0.20	0.20
	(2) 22	0.13	0.16	0.18	0.17	0.18	0.20	0.15	0.19	0.22	0.21	0.18	0.21	0.17	0.18	0.22	0.22	0.20	0.20
	(3) 44	0.14	0.16	0.18	0.17	0.17	0.18	0.15	0.19	0.21	0.21	0.20	0.21	0.16	0.19	0.22	0.22	0.20	0.21
	(4) 88	0.15	0.16	0.20	0.18	0.18	0.18	0.17	0.18	0.21	0.22	0.20	0.21	0.17	0.19	0.21	0.21	0.18	0.21
	Average	0.14 ±0.01	0.16 ±0.00	0.19 ±0.01	0.17 ±0.00	0.17 ±0.01	0.18 ±0.01	0.16 ±0.01	0.19 ±0.01	0.21 ±0.00	0.21 ±0.01	0.19 ±0.01	0.21 ±0.00	0.17 ±0.00	0.19 ±0.00	0.21 ±0.01	0.21 ±0.01	0.19 ±0.01	0.20 ±0.01

Table 7. Phosphorus content (% in dry matter) and it's uptake (kg P/ha) in alfalfa-orchardgrass mixture as affected by maintenance K fertilizer

Treatment kg K/ha annually	Year	1st cut					2nd cut					3rd cutAL					P uptake annually		
		AL		OG		Total	AL		OG		Total	AL		OG		Total			
		%	Uptake	%	Uptake	P uptake	%	Uptake	%	Uptake	P uptake	%	Uptake	%	Uptake	P uptake	LC	OG	Total
No K	1965	0.20	0.985	0.19	2.132	3.117	0.20	0.234	0.21	2.488	2.722	0.19	0.895	0.20	1.695	2.590	2.114	6.316	8.429
	1966	0.20	0.174	0.19	1.801	1.975	0.21	0.290	0.21	2.153	2.443	0.19	0.080	0.20	1.426	1.506	0.544	5.380	5.924
	1967	0.20	0.223	0.19	3.944	4.167	0.21	0.307	0.21	2.226	2.533	0.20	0.228	0.20	1.980	2.208	0.758	8.150	8.908
	1968	0.18	0.144	0.18	2.628	2.772	0.20	0.140	0.19	1.925	2.065	0.19	0.048	0.19	1.098	1.146	0.332	5.651	5.983
	1969	0.13	0.146	0.16	1.578	1.724	0.17	0.203	0.18	2.889	3.091	0.18	0.058	0.18	0.195	1.253	0.406	5.662	6.068
	Total	0.18	1.672	0.18	12.083	13.755	0.20	1.174	0.20	11.681	12.854	0.19	1.309	0.19	6.394	8.703	4.154	31.159	35.312
		±0.03		±0.01			±0.02		±0.01			±0.01		±0.01					
250	1965	0.18	1.749	0.20	3.636	5.385	0.21	2.266	0.22	4.347	6.613	0.19	0.868	0.19	1.807	2.675	4.883	9.791	14.674
	1966	0.20	1.630	0.20	3.566	5.196	0.21	2.289	0.21	3.749	6.038	0.20	1.150	0.20	3.680	3.830	5.069	9.995	15.064
	1967	0.21	2.717	0.20	6.168	8.885	0.21	2.405	0.21	3.196	5.601	0.21	1.308	0.20	2.619	3.927	6.431	11.983	18.413
	1968	0.18	3.564	0.19	3.046	6.610	0.20	3.600	0.21	3.083	6.683	0.20	1.614	0.20	2.626	4.240	8.778	8.755	17.533
	1969	0.15	1.831	0.18	1.752	3.583	0.19	2.474	0.21	3.655	6.130	0.19	2.289	0.20	2.047	4.335	6.594	7.454	14.048
	Total	0.18	11.491	0.19	18.168	29.659	0.20	13.034	1.06	18.030	31.065	0.20	7.229	0.20	12.779	19.007	31.755	47.978	79.732
		±0.02		±0.01			±0.01		±0.00			±0.01		±0.00					
500	1965	0.21	1.790	0.21	3.974	5.764	0.21	2.282	0.21	4.384	6.666	0.19	0.922	0.20	1.892	2.815	4.994	10.250	15.245
	1966	0.20	1.810	0.21	3.776	5.586	0.20	2.410	0.21	4.295	6.705	0.20	1.180	0.20	2.860	4.040	5.400	10.931	16.331
	1967	0.20	2.718	0.22	7.082	9.800	0.20	2.150	0.22	3.575	5.725	0.20	1.405	0.20	2.940	4.346	6.273	13.598	19.871
	1968	0.18	3.451	0.19	2.894	6.345	0.20	3.514	0.22	3.362	6.876	0.20	1.430	0.20	2.874	4.304	8.395	9.130	17.525
	1969	0.15	2.379	0.18	1.424	3.803	0.20	2.902	0.22	4.057	6.959	0.19	2.488	0.20	2.224	4.712	7.769	7.705	15.474
	Total	0.19	12.148	0.20	19.150	31.298	0.20	13.258	0.22	19.673	32.931	0.20	7.425	0.20	12.790	20.217	32.831	51.614	84.446
		±0.02		±0.02			±0.00		±0.01			±0.01		±0.00					

Table 8. Phosphorus content (% in dry matter) and it's uptake (kg P/ha) in Ladinoclover-orchardgrass mixture as affected by maintenance K fertilizer

Treatment kg K/ha annually	Year	1st cut					2nd cut					3rd cut					P uptake annually		
		LC		OG		Total	LC		OG		Total	LC		OG		Total	CL	OG	Total
		%	Uptake	%	Uptake	P uptake	%	Uptake	%	Uptake	P uptake	%	Uptake	%	Uptake	P uptake			
No K	1965	0.21	0.346	0.19	1.684	2.030	0.20	0.138	0.20	2.333	2.472	0.20	0.103	0.20	1.677	1.780	0.588	5.694	6.282
	1966	0.20	0.300	0.20	1.906	2.206	0.20	1.416	0.20	2.210	2.626	0.20	0.060	0.20	1.450	1.510	0.776	5.566	6.342
	1967	0.20	0.489	0.21	5.441	5.930	0.21	0.559	0.20	2.457	3.016	0.21	0.156	0.20	2.102	2.258	1.204	10.000	11.204
	1968	0.16	0.200	0.17	1.934	2.134	0.20	0.414	0.18	2.165	2.579	0.18	0.076	0.19	1.925	2.001	0.690	6.024	6.714
	1969	0.14	0.237	0.16	1.441	1.678	0.19	0.166	0.17	2.729	2.895	0.17	0.103	0.18	1.329	1.433	0.506	5.500	6.006
	Total	0.18	1.572	0.19	12.406	13.978	0.20	1.693	0.19	11.894	13.588	0.19	0.498	0.19	8.483	8.982	3.764	32.784	36.548
		±0.03		±0.02			±0.01		±0.01			±0.02		±0.01					
250	1965	0.21	1.628	0.20	3.134	4.763	0.22	2.036	0.21	4.058	6.094	0.20	0.698	0.21	1.707	2.405	4.362	8.899	13.262
	1966	0.20	1.760	0.20	3.296	5.056	0.21	2.447	0.21	3.801	6.248	0.20	1.110	0.21	3.024	4.134	5.317	10.121	15.438
	1967	0.19	1.914	0.20	8.059	9.973	0.21	1.381	0.21	3.754	5.135	0.20	0.864	0.21	3.319	4.183	4.159	15.131	19.291
	1968	0.18	1.355	0.19	6.185	7.540	0.21	3.360	0.21	3.833	7.193	0.20	1.384	0.21	2.820	4.204	6.099	12.838	18.937
	1969	0.16	0.943	0.19	2.497	3.440	0.21	2.189	0.21	3.737	5.927	0.19	1.421	0.21	2.570	3.991	4.553	8.805	13.358
	Total	0.19	7.600	0.20	23.171	30.772	0.21	11.413	0.21	19.183	30.597	0.20	5.477	0.21	13.440	18.917	24.490	55.794	80.286
		±0.02		±0.01			±0.00		±0.00			±0.00		±0.00					
500	1965	0.21	1.834	0.21	3.673	5.507	0.22	2.120	0.21	4.247	6.367	0.19	0.682	0.20	1.709	2.391	4.636	9.629	14.265
	1966	0.21	1.974	0.20	3.306	5.280	0.21	2.514	0.21	3.860	6.374	0.20	1.130	0.20	2.956	4.086	5.618	10.122	15.740
	1967	0.21	2.114	0.20	8.133	10.247	0.21	1.424	0.21	3.781	5.205	0.21	1.021	0.21	3.401	4.422	4.560	15.314	19.874
	1968	0.18	0.969	0.19	2.698	3.667	0.21	2.352	0.21	4.190	6.542	0.20	1.576	0.20	2.700	4.276	4.897	9.588	14.485
	1969	0.17	0.955	0.19	2.665	3.620	0.21	2.408	0.21	4.290	6.698	0.19	1.536	0.20	2.769	4.306	4.899	9.724	14.624
	Total	0.20	7.846	0.20	20.475	28.321	0.21	10.818	0.21	20.368	31.186	0.20	5.945	0.20	13.535	19.481	24.610	54.377	78.988
		±0.02		±0.01			±0.00		±0.00			±0.01		±0.00					

Table 9. Effect of rates of phosphorus and potassium on dry matter Second five years in kg/ha

kg P/ha[1]	No K	250 kg K[2]	500 kg K[3]
	(a) Alfalfa-orchardgrass		
(1) 0	17,170	39,600	40,850
(2) 22	17,090	40,160	41,240
(3) 44	17,990	39,790	41,020
(4) 88	17,560	39,920	41,370
(4) Average/year	3,510	7,980	8,270
	(b) Ladino clover-orchardgrass		
(1) 0	18,960	38,800	40,600
(2) 22	19,400	40,080	40,530
(3) 44	18,470	39,810	41,580
(4) 88	19,160	39,040	41,030
(4) Average/year	3,830	7,810	8,210

(1) P banded under seed as superphosphate (20% P_2O_5)
(2) K supplied by 83 kg K/ha after each of three cuttings annually=250
(3) and 167 kg K/ha after each of three cuttings=500 kg K/ha.

Table 10. Phosphorus removed in forage (kg P/ha)

Treatment kg P/ha	1960	1961–64	1965–69	Total	Deficient soil P
		(a) Alfalfa-orchardgrass			
(1) 0	3.01	60.54	77.00	140.6	−140.6
(2) 22	5.44	68.06	81.11	154.6	−132.6
(3) 44	7.63	71.89	80.54	160.1	−116.1
(4) 88	11.04	72.02	81.39	164.5	− 76.5
		(b) Ladino clover-orchardgrass			
(1) 0	3.63	57.65	76.90	138.2	−138.2
(2) 22	4.54	67.99	80.52	153.1	−131.1
(3) 44	5.09	72.63	81.42	159.1	−115.1
(4) 88	7.92	74.66	80.49	163.1	− 75.1

250 kg K/ha annually. 1966 and 1968 dry matter was estimated at 0.2%P.

to 33 to 50 per cent for alfalfa growing on plots that received K after each cutting. Ladino clover without annual K contributed only 9 to 12 per cent of the yield as compared to 22 to 35 per cent with fertilizer K. Both the medium and high rates of potassium produced relatively high yields of forage (Table 9.). Average annual dry matter for no K, 250 K and 500 K, respectively, were 3510, 7980 and 8270 for alfalfa-orchardgrass and 3830, 7810 and 8210 for Ladino clover-orchardgrass mixtures. Thus, annual applications of fertilizer K after each cutting more than doubled dry matter yields of both alfalfa-orchardgrass and Ladino clover-orchardgrass mixtures during this second five year period, 1965–1969.

Table 11. Potassium content (% in dry matter) of legume and of grass in alfalfa-orchardgrass mixture as affected by maintenance K fertilizer (kg K/ha)

Year	kg P/ha	No K						250 kg K						500 kg K					
		1st cut		2nd cut		3rd cut		1st cut		2nd cut		3rd cut		1st cut		2nd cut		3rd cut	
		AL	OG	AL	OG	AL	OG	AL	OG	AL	OG	AL	OG	AL	OG	AL	OG	AL	OG
1965	(1) 0	1.65	2.03	1.57	1.97	1.82	1.91	3.45	3.81	3.76	4.08	4.20	4.46	3.47	3.99	3.91	4.11	4.36	4.46
	(2) 22	1.61	2.11	1.70	2.02	1.76	1.96	3.49	3.91	3.81	3.95	4.26	4.31	3.56	4.03	3.96	4.04	4.31	4.50
	(3) 44	1.73	1.99	1.65	2.00	1.80	1.93	3.53	3.83	3.91	4.02	4.30	4.40	3.52	3.90	3.90	4.17	4.46	4.31
	(4) 88	1.71	1.95	1.75	2.06	1.80	1.95	3.44	3.91	3.88	4.07	4.29	4.39	3.48	3.92	3.98	4.05	4.36	4.50
	Average	1.67	2.02	1.65	2.01	1.80	1.94	3.48	3.86	3.84	4.03	4.26	4.39	3.51	3.96	3.94	4.09	4.37	4.44
		±0.06	±0.07	±0.08	±0.04	±0.03	±0.02	±0.04	±0.05	±0.07	±0.06	±0.05	±0.06	±0.04	±0.06	±0.04	±0.06	±0.06	±0.09
1967	(1) 0	1.57	2.12	1.75	2.08	1.65	1.78	3.27	3.55	3.91	4.19	4.13	4.25	3.22	3.63	4.02	4.35	4.20	4.31
	(2) 22	1.52	2.19	1.70	2.06	1.73	1.76	3.38	3.63	3.88	4.23	4.16	4.34	4.42	3.57	3.98	4.23	4.17	4.36
	(3) 44	1.65	2.05	1.74	2.03	1.70	1.86	3.22	3.60	3.94	4.18	4.17	4.27	3.36	3.62	4.09	4.29	4.23	4.44
	(4) 88	1.69	2.11	1.69	2.11	1.67	1.72	3.36	3.65	3.93	4.24	4.14	4.30	3.41	3.69	4.04	4.30	4.19	4.30
	Average	1.61	2.12	1.72	2.07	1.69	1.78	3.31	3.61	3.91	4.21	4.15	4.29	3.35	3.63	4.03	3.29	4.20	4.35
		±0.08	±0 06	±0.03	±0.03	±0.04	±0.06	±0.08	±0.04	±0.03	±0.03	±0.02	±0.04	±0.09	±0.05	±0.05	±0.05	±0.03	±0.06
1969	(1) 0	1.34	1.86	1.65	2.03	1.73	1.78	3.46	3.70	4.16	4.35	4.20	4.27	3.52	3.87	4.25	4.50	4.28	4.44
	(2) 22	1.24	1.69	1.52	2.06	1.67	1.84	3.41	3.80	4.08	4.30	4.25	4.40	3.68	3.92	4.35	4.44	4.35	4.29
	(3) 44	1.41	1.82	1.63	1.99	1.69	1.72	3.41	3.80	4.12	4.44	3.58	3.82	3.58	3.82	4.44	4.56	4.21	4.47
	(4) 88	1.31	1.77	1.62	1.97	1.73	1.78	3.47	3.90	4.17	4.47	4.23	4.38	3.62	3.91	4.28	4.48	4.27	4.47
	Average	1.32	1.78	1.60	2.01	1.70	1.78	3.44	3.80	4.13	4.39	4.23	4.37	3.60	3.88	4.33	4.49	4.28	4.42
		±0.07	±0.07	±0.06	±0.04	±0.03	±0.05	±0.03	±0.08	±0.04	±0.08	±0.02	±0.07	±0.07	±0.05	±0.08	±0.05	±0.06	±0.09

Table 12. Potassium content (% in dry matter) of legume and of grass in Ladino clover-orchardgrass mixture as affected by maintenance K fertilizer (kg K/ha)

Year	kg P/ha	No K						250 kg K						500 kg K					
		1st cut		2nd cut		3rd cut		1st cut		2nd cut		3rd cut		1st cut		2nd cut		3rd cut	
		LC	OG	LC	OG	LC	OG	LC	OG	LC	OG	LC	OG	LC	OG	LC	OG	LC	OG
1965	(1) 0	1.78	2.00	1.67	2.02	1.78	1.90	3.48	3.90	3.92	3.97	4.17	4.41	3.51	4.01	4.04	4.14	4.43	4.50
	(2) 22	1.72	2.08	1.63	2.06	1.84	1.97	3.52	3.84	3.95	4.01	4.24	4.47	3.54	3.96	3.96	4.10	4.40	4.55
	(3) 44	1.80	1.99	1.69	1.99	1.81	1.95	3.44	3.91	3.91	4.05	4.27	4.44	3.53	4.07	4.05	4.05	4.34	4.42
	(4) 88	1.73	2.11	1.67	2.01	1.79	1.91	3.53	3.91	3.96	3.95	4.22	4.36	3.52	3.96	4.02	4.11	4.45	4.49
	Average	1.76	2.04	1.66	2.02	1.89	1.93	3.49	3.89	3.94	3.99	4.22	4.42	3.52	4.00	4.02	4.10	4.41	4.49
		0.04	0.06	0.03	0.03	0.03	0.03	0.04	0.03	0.02	0.04	0.04	0.05	0.01	0.05	0.04	0.04	0.05	0.05
1967	(1) 0	1.59	2.10	1.84	2.13	1.62	1.81	3.18	3.57	4.01	4.24	4.12	4.28	3.31	3.56	4.00	4.30	4.17	4.29
	(2) 22	1.57	2.14	1.80	2.18	1.67	1.78	3.32	3.54	3.99	4.29	4.18	4.30	3.38	3.63	4.03	4.40	4.24	4.37
	(3) 44	1.62	2.10	1.79	2.10	1.65	1.77	3.27	3.63	3.95	4.35	4.13	4.27	3.22	3.65	4.01	4.44	4.20	4.47
	(4) 88	1.67	2.19	1.85	2.12	1.70	1.72	3.23	3.63	3.97	4.27	4.16	4.31	3.33	3.65	4.02	4.42	4.17	4.31
	Average	1.61	2.13	1.82	2.13	1.66	1.77	3.25	3.59	3.98	4.29	4.15	4.29	3.31	3.62	4.01	4.39	4.19	4.36
		0.04	0.04	0.03	0.03	0.03	0.04	0.06	0.04	0.03	0.05	0.03	0.02	0.07	0.04	0.01	0.06	0.03	0.08
1969	(1) 0	1.03	1.77	1.73	1.94	1.65	1.84	3.51	3.80	4.05	4.28	4.23	4.35	3.51	3.94	4.19	4.46	4.44	4.47
	(2) 22	1.36	1.84	1.61	2.03	1.76	1.82	3.46	3.77	4.12	4.40	4.20	4.30	3.55	3.88	4.27	4.39	4.30	4 44
	(3) 44	1.30	1.65	1.67	2.06	1.71	1.79	3.46	3.77	4.11	4.46	4.37	4.40	3.68	3.90	4.23	4.51	4.30	4.44
	(4) 88	1.25	1.60	1.63	2.00	1.73	1.79	3.47	3.79	4.08	4.44	4.27	4.44	3.65	3.97	4.16	4.42	4.47	4.44
	Average	1.23	1.72	1.66	2.01	1.72	1.81	3.47	3.78	4.09	4.39	4.27	4.37	3.60	3.92	4.21	4.44	4.40	4.49
		0.14	0.11	0.05	0.05	0.04	0.02	0.02	0.01	0.03	0.08	0.07	0.06	0.08	0.04	0.05	0.05	0.07	0.02

Table 13. Effect of potassium level on total dry matter (kg/ha), per cent alfalfa in the mixture with orchardgrass and K content

Year	No K			250 kg K/ha			500 kg K/ha		
	% legume	dry matter	kg K	% legume	dry matter	kg K	% legume	dry matter	kg K
				(a) alfalfa-orchardgrass					
1965	6.3	3333	65.81	34.0	7133	281.84	33.1	7380	297.43
1966[1)]	9.1	2953	58.47	33.6	7388	288.13	33.9	7973	322.91
1967	8.4	4458	89.02	34.0	8983	345.14	33.0	8880	367.80
1968[2)]	4.7	3225	62.24	51.2	8970	355.21	49.4	8878	369.32
1969	7.4	3485	65.04	49.9	7395	302.0	53.2	8010	335.30
Total			340.6			1572.3			1692.8
K applied			0.0			1250			2500

1) Per cent K for 1966 were estimated at 1.98% in No K, 3.90% in 250 kg K/ha and 4.05% in 500 kg K/ha.
2) Per cent K for 1968 were estimated at 1.93%, 3.96% and 4.16% respectively.

Table 14. Effect of potassium level on total dry matter (kg/ha), per cent Ladino clover in the mixture with orchardgrass and K content

Year	No K			250 kg K/ha			500 kg K/ha		
	% legume	dry matter	kg K	% legume	dry matter	kg K	% legume	dry matter	kg K
				(b) Ladino clover-orchardgrass					
1965	9.1	3155	62.46	32.6	6345	251.64	32.3	6733	272.98
1966[1)]	12.2	3170	63.40	34.7	7495	293.80	35.3	7670	305.27
1967	10.6	5408	109.70	22.2	9380	361.86	22.6	9540	373.66
1968[2)]	10.0	3728	71.95	32.2	9467	377.73	29.3	9750	397.80
1969	8.8	3538	65.15	35.2	6745	278.29	34.2	7243	306.97
Total			372.7			1563.3			1656.7
K applied			0.0			1250			2500

1) Per cent K for 1966 were estimated at 2.00% in No K, 3.92% in 250 kg K/ha and 3.98% in 500 kg K/ha.
2) Per cent K for 1968 were estimated at 1.93%, 3.99% and 4.08% respectively.

When no fertilizer K was supplied, the per cent K in both alfalfa and Ladino clover declined each year. Alfalfa contained 1.71, 1.68 and 1.50 and Ladino clover contained 1.74, 1.71 and 1.44 per cent K, respectively, in years 1965, 1967 and 1969 (Tables 11 and 12). Alfalfa and Ladino clover plants growing at these very low levels of K lost vigor and almost disappeared from the orchardgrass mixtures.

Alfalfa which received 83 kg K after each cutting (250 kg K annually) was 33 to 50 per cent of the stand, made vigorous growth, and contained from 3.70 to 3.94 per cent K. Ladino clover that received 83 kg K after each cutting was vigorous and ranged from 3.21 to 3.99 per cent K. Orchardgrass from the alfalfa and Ladino clover mixtures was vigorous and contained 3.91 to 4.23 per cent K.

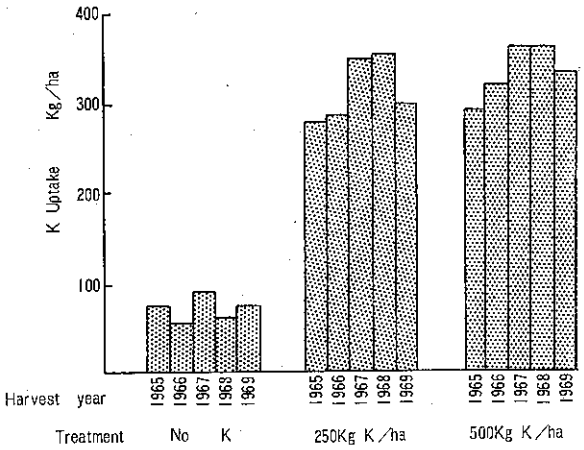

Fig. 1. Uptake of K by K fertilizer topdressing in alfalfa-orchardgrass mixture

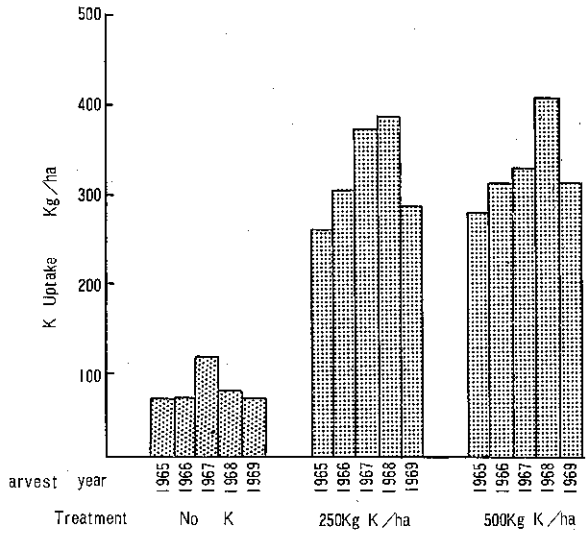

Fig. 2. Uptake of K by K fertilizer topdressing in ladino clover-orchardgrass mixture

Alfalfa receiving 167 kg K after each cutting (500 kg K annually) ranged from 3.87 to 4.05; Ladino clover from 3.73 to 4.14; and orchardgrass from 3.97 to 4.34 per cent K.

As indicated in Tables 11 and 12, the K content of forages not receiving a topdressing of K was lower than those with topdressing of K. A heavy topdressing of 500 kg K/ha annually brought an increase of K content comparable to light or no topdressing of K. The potassium content of orchardgrass was higher than that of alfalfa and Ladino clover. Comparing the yearly variation

of K content, the K content of legumes and orchardgrass in 1969 was lower than that in 1965 and 1967.

Although the application of 83 kg K after each cutting produced high yields of forage with desirable K content, the total K removed by forage in five years was greater than the K supplied as fertilizer (1572 kg K contained in alfalfa-orchardgrass and 1563 contained in Ladino clover-orchardgrass as compared to 1250 kg K/ha as fertilizer K).

The favorable effect of potassium fertilizer in maintaining desirable stands of both alfalfa and Ladino clover in association with orchardgrass, increased the nitrogen level in the forage (Table 14). This favorable effect of potassium fertilizer application after each cutting helped to maintain the Ladino clover and alfalfa and greatly favored the nitrogen economy of these legume-orchardgrass mixtures. Alfalfa-orchardgrass yields were increased 2.3 times by applying fertilizer K after each cutting; nitrogen content in this forage was increased from 2.30 per cent N (low K) to 3.20 for high K; and the total nitrogen yields were increased by factors of 2.91, 2.67 and 3.01 (for 250 kg K annually) and by 3.02, 2.80 and 3.34 (500 kg K), respectively, for years 1965, 1967 and 1969.

Nitrogen Similarly, dry matter yields of Ladino clover were more than doubled by applying K after each cutting; nitrogen in the forage was increased from 2.30 per cent N (low K) to over 3.00 per cent N for high K; and the total nitrogen yields were increased by factors of 2.66, 2.27 and 2.53 (for 250 kg K annually) and 2.86, 2.32 and 2.75 (for 500 kg K), respectively, in 1965, 1967 and 1969.

As shown in Tables 15 and 16, the N contents of legumes and orchardgrass varied with the kinds of mixtures, the cutting stage and the topdressing of K. Particularly, the application of K increased the N contents of forages remarkably over those with no topdressing of K. In general, the nitrogen of forages in mixtures originates from rhizobium bacteria and natural sources such as nitrogen in soil, water etc. From this data, it may be assumed that K application strikingly accerelated the activity of rhizobium bacteria which fix free nitrogen from the air. Therefore, the amounts of nitrogen uptake by legumes were markedly affected by the topdressing of K, and by the legume used in the mixture.

Statistical analysis

The relationships affecting on dry matter yield and nutrient uptake by forage mixtures with K application have been computed by F test from Tables 3, 4, 7, 8, 13, 14, 15 and 16. The results, as shown in Table 17, indicate that a significant difference at the level of 1% appeared on the yearly total of dry matter and the ratio of legumes with the topdressing of potassium in alfalfa-orchardgrass

Table 15. Nitrogen content (% in dry matter) and it's uptake (kg N/ha) in alfalfa-orchardgrass mixture as affected by maintenance K fertilizer

Treatment kg K/ha annually	Year	1st cut					2nd cut			
		AL		OG		Total	AL		OG	
		%	Uptake	%	Uptake	N uptake	%	Uptake	%	Uptake
No K	1965	3.09	1.478	1.95	21.169	22.647	3.20	3.681	2.17	26.072
	1966	3.15	2.772	2.00	21.700	24.472	3.30	3.795	2.21	26.520
	1967	3.21	3.632	2.07	41.871	45.503	3.32	4.895	2.28	24.241
	1968	3.22	2.576	2.18	31.828	34.404	3.36	2.352	2.23	22.590
	1969	3.22	3.475	2.00	19.358	22.832	3.46	4.058	2.25	35.651
	Total	3.18	13.933	2.04	135.926	149.858	3.33	18.781	2.23	135.074
		±0.06		±0.09			±0.09		±0.04	
250	1965	3.66	33.319	2.39	43.540	76.859	3.59	38.280	2.72	53.340
	1966	3.59	29.259	2.42	43.149	72.408	3.60	39.240	2.81	50.159
	1967	3.67	47.963	2.49	77.578	125.540	3.65	40.796	2.86	42.583
	1968	3.20	63.360	2.53	40.556	103.916	3.72	66.960	2.80	41.104
	1969	3.59	43.031	2.35	23.452	66.483	3.96	50.305	2.72	46.287
	Total	3.54	216.932	2.44	228.275	445.206	3.70	235.581	2.78	233.473
		±0.19		±0.07			±0.15		±0.06	
500	1965	3.67	31.671	2.37	44.919	76.589	3.67	40.390	2.78	57.968
	1966	3.65	33.033	2.35	42.253	75.286	3.66	44.103	2.80	57.260
	1967	3.68	49.438	2.52	81.148	130.585	3.65	39.290	2.80	46.780
	1968	3.62	69.400	2.46	37.220	106.620	3.72	65.360	2.81	42.937
	1969	3.64	55.790	2.44	19.596	75.386	4.01	57.408	2.76	51.421
	Total	3.65	239.332	2.43	225.136	464.466	3.74	246.551	2.79	256.366
		±0.02		±0.07			±0.15		±0.02	

Treatment kg K/ha annually	Year	3rd cut						N uptake annually		
		Total	AL		OG		Total	AL	OG	Total
		N uptake	%	Uptake	%	Uptake	N uptake			
No K	1965	29.754	3.53	1.678	2.34	19.563	21.241	6.837	66.804	73.642
	1966	30.315	3.52	1.654	2.30	19.274	20.928	8.221	67.494	75.715
	1967	29.135	3.48	3.749	2.28	22.769	26.518	12.526	88.880	101.156
	1968	24.942	3.51	0.878	2.23	12.889	13.767	5.806	67.307	73.113
	1969	39.709	3.51	1.142	2.35	15.856	16.998	8.675	70.864	79.540
	Total	153.855	3.51	9.101	2.30	90.351	99.452	42.065	361.349	403.166
			±0.02		±0.05					
250	1965	91.620	4.10	18.235	2.83	26.577	44.812	89.833	123.458	213.291
	1966	89.399	4.09	23.518	2.81	37.654	61.172	92.017	130.962	222.979
	1967	83.379	4.04	25.478	2.78	36.864	62.342	114.237	157.024	271.261
	1968	108.064	4.07	32.845	2.82	37.027	69.872	163.165	118.687	281.852
	1969	96.592	4.05	49.468	2.82	28.453	77.922	142.805	97.943	240.998
	Total	469.054	4.07	149.544	2.81	166.575	316.120	603.057	628.074	1230.381
			±0.03		±0.02					
500	1965	98.358	4.12	19.758	2.81	26.928	46.686	91.819	129.814	221.633
	1966	101.363	4.10	24.190	2.80	56.560	80.750	101.326	156.073	257.399
	1967	86.070	4.06	27.789	2.80	40.031	67.820	116.516	167.959	284.475
	1968	108.297	4.07	29.101	2.80	40.236	69.337	163.861	120.393	284.254
	1969	108.829	4.06	52.367	2.82	30.582	82.949	165.565	101.599	267.164
	Total	502.917	4.08	153.205	2.81	194.337	347.542	639.087	675.838	1314.925
			±0.03		±0.01					

Table 16. Nitrogen content (% in dry matter) and it's uptake (kg K/ha) in Ladino clover-orchardgrass mixture as affected by maintenance K fertilizer

Treatment kg K/ha annually	Year	1st cut					2nd cut			
		LC		OG		Total	LC		OG	
		%	Uptake	%	Uptake	N uptake	%	Uptake	%	Uptake
No K	1965	3.17	5.148	1.99	17.198	22.346	3.40	2.387	2.23	25.788
	1966	3.30	4.950	2.04	19.441	24.391	3.40	7.072	2.30	25.415
	1967	3.40	8.084	2.10	53.770	61.854	3.49	9.157	2.31	29.115
	1968	3.35	4.188	2.08	23.670	27.858	3.45	7.142	2.33	28.030
	1969	3.32	5.490	2.07	18.920	24.410	3.51	3.076	2.32	36.665
	Total	3.31	27.860	2.06	132.999	160.859	3.45	28.834	2.30	145.013
		±0.09		±0.04			±0.05		±0.04	
250	1965	3.62	28.407	2.44	37.724	66.132	3.86	36.080	2.69	51.343
	1966	3.65	32.120	2.45	40.376	72.496	3.90	45.435	2.70	48.870
	1967	3.69	37.172	2.48	97.659	134.831	3.93	25.254	2.81	50.313
	1968	3.71	19.663	2.42	78.771	98.434	3.92	62.400	2.72	49.640
	1969	3.78	22.710	2.40	32.400	55.110	4.06	41.840	2.71	48.323
	Total	3.69	140.072	2.44	286.930	427.003	3.93	211.009	2.73	248.489
		±0.06		±0.03			±0.08		±0.05	
500	1965	3.63	30.993	2.46	42.667	73.660	3.90	37.656	2.79	55.218
	1966	3.65	34.310	2.48	40.994	75.304	3.91	46.803	2.80	51.464
	1967	3.70	36.783	2.50	99.288	136.079	3.92	25.964	2.81	50.677
	1968	3.75	24.750	2.51	88.176	112.926	3.95	58.737	2.78	55.822
	1969	3.82	21.803	2.53	35.999	57.802	4.08	45.691	2.74	54.758
	Total	3.71	148.639	2.50	307.124	455.771	3.95	214.851	2.78	267.939
		±0.08		±0.03			±0.07		±0.03	

Treatment kg K/ha annually	Year	3rd cut					N uptake annually		
		Total	LC		OG		Total			
		N uptake	%	Uptake	%	Uptake	N uptake	LC	OG	Total
No K	1965	28.176	3.53	1.856	2.29	19.517	21.374	9.392	62.504	71.896
	1966	32.487	3.12	0.936	2.10	15.225	16.161	12.958	60.081	73.039
	1967	38.272	2.28	1.710	1.77	18.363	20.072	18.951	101.247	120.198
	1968	35.172	2.82	1.184	2.08	21.070	22.254	12.514	72.770	85.284
	1969	39.741	3.51	2.107	2.34	17.055	19.162	10.673	72.639	83.313
	Total	173.848	3.05	7.793	2.12	91.230	99.023	64.488	369.241	433.730
			±0.52		±0.22					
250	1965	87.423	4.18	14.439	2.84	23.397	37.836	78.926	112.465	191.391
	1966	94.305	4.12	22.866	2.80	40.320	63.186	100.421	129.566	229.987
	1967	75.568	4.11	17.798	2.79	44.074	61.873	80.225	192.047	272.272
	1968	112.040	4.10	28.372	2.81	37.738	66.110	110.435	166.149	276.584
	1969	90.163	4.07	30.460	2.82	34.927	65.387	95.011	115.650	210.661
	Total	459.499	4.12	113.935	2.81	180.456	294.392	465.018	715.877	1180.895
			±0.03		±0.02					
500	1965	92.874	4.16	14.777	2.81	24.012	38.789	83.426	121.897	205.323
	1966	98.267	4.15	23.448	2.82	41.680	65.128	104.561	134.138	238.699
	1967	76.641	4.13	20.333	2.81	45.519	65.852	83.079	195.484	278.563
	1968	114.559	4.10	29.233	2.85	39.045	68.278	112.720	183.043	295.763
	1969	100.449	4.08	32.177	2.86	38.633	70.810	99.671	129.390	229.062
	Total	482.790	4.12	119.968	2.83	188.889	308.857	483.457	763.952	1247.410
			±0.03		±0.02					

Table 17. Statistical analysis of dry matter, ratio of legumes and nutrient uptake with the application of potassium

1. Annual dry matter in alfalfa-orchardgrass mixture

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
K treatment	213650000	2	106830000	189.9**
Year	14628000	4	3657000	6.5**
K treatment × Year	4427800	8	553470	61.3**
Error	270850	30	9028	
Total	232980000	44		

Remarks: * siguifiant at 5 %, ** significant at 1 % level.

2. Annual dry matter in Ladino clover-orchardgrass mixture

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
K treatment	23049000	2	11524000	60.4**
Year	1982500	4	495620	2.6
K treatment × Year	1495600	8	186940	48.0**
Error	116740	30	3891	
Total	26643000	44		

3. Ratio of alfalfa in alfalfa-orchardgrass mixture

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
K treatment	11076	2	5537.80	47.66**
Year	1295	4	323.63	2.79*
K treatment × Year	927	8	115.94	465.19**
Error	7	30	0.25	
Total	13305	44		

4. Ratio of Ladino clover in Ladino clover-orchardgrass mixture

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
K treatment	4370	2	2185.10	70.13**
Year	423	4	105.83	3.40*
K treatment × Year	247	8	30.86	103.09**
Error	9	30	0.30	
Total	5049	44		

5. P uptake by forages in alfalfa-orchardgrass mixture

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
K treatment	875.33	2	437.66	109.34**
Year	80.55	4	20.14	5.03**
K treatment × Year	30.98	8	3.87	29.84**
Error	3.89	30	0.13	
Total	990.75	44		

6. P uptake by forages in Ladino clover-orchardgrass mixture

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
K treatment	732.47	2	366.23	65.14**
Year	181.25	4	45.31	8.06**
K treatment × Year	42.84	8	5.35	19.99**
Error	8.04	30	0.27	
Total	964.59	44		

7. K uptake by forages in alfalfa-orchardgrass mixture

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
K treatment	672070	2	336040	374.2**
Year	19641	4	4910	5.5**
K treatment × Year	6879	8	859	22.5**
Error	1147	30	38	
Total	699740	44		

8. K uptake by forages in Ladino clover-orchardgrass mixture

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
K treatment	614830	2	307410	154.9**
Year	57901	4	14475	7.8**
K treatment × Year	155980	8	1949	55.5**
Error	1053	30	35	
Total	689380	44		

9. N uptake by forages in alfalfa-orchardgrass mixture

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
K treatment	303790	2	151890	205.1**
Year	14634	4	3659	4.9**
K treatment × Year	5672	8	709	22.4**
Error	948	30	32	
Total	325040	44		

10. N uptake by forages in Ladino clover-orchardgrass mixture

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
K treatment	248220	2	124110	145.9**
Year	29825	4	7456	8.8**
K treatment × Year	6535	8	817	24.5**
Error	1001	30	33	
Total	285580	44		

and Ladino clover-orchardgrass mixtures. Annual P.K.N uptake absorbed by forage mixtures was statistically significant at the level of 1% with the topdressing of potassium, also.

The Role of Weather Factors

The remarkable performance of alfalfa-orchardgrass and Ladino clover-orchardgrass forage seeding mixture over a ten year period at Obihiro on the island of Hokkaido in Japan is quite unusual. In most areas or regions where these forage mixtures are grown maximum or near maximum production does not extend beyond a period of from two to three years even when adequately fertilized and carefully managed. In most instances it is difficult to maintain the legume stands. For example, at Amherst, Massachusetts, the orchardgrass in Ladino clover-orchardgrass mixtures tends to dominate after two or three years, especially if there have been periods of below normal rainfall. Alfalfa because of its deeply penetrating roots and aggressive growth habit is more persistent than Ladino clover. In fact, alfalfa frequently dominates the mixture for the first year or two. Following this initial period orchardgrass together with varying amounts of volunteer grasses especially Kentucky bluegrass (*Poa pratensis*) progressively take over so that in three to five years only scattered alfalfa plants remain.

Just why Ladino clover and alfalfa in mixtures with orchardgrass should persist and be productive so much longer in Obihiro, Japan, than at Amherst, Massachusetts, is difficult to explain. There must be significant differences in some important environmental factors between the two locations. Of the environmental factors to by considered weather factors such as rainfall, temperature and hours of sunshine are by far the most important. Although Obihiro, Japan and Amherst, Massachusetts are widely separated geographically, they lie at approximately the same northern latitude and climate in general is similar for both locations. However, there are substantial and significant differences in the specific weather patterns characteristic for each location. These differences are shown in Table 18 for mean temperatures, in Table 19 for precipitation amounts and in Table 20 for hours of sunshine. Only the weather data for the five summer months (May through September) and for just the five years of the experiment reported in this paper are shown for Obihiro. The comparative weather data for Amherst for the same months are long time averages for the period of years from 1889 to 1958.

From Table 18 it is evident that seasonal growing temperatures at Obihiro are significantly lower than they are at Amherst, especially for the first three months of the growing season, May, June and July. Plant growth at Obihiro not only begins late in the season but also proceeds at a slower growth rate. A slower growth rate would reduce if not eliminate any stresses on soluble carbohydrate reserves even at high levels of nitrogen fertilization. Cooler growing temperatures would therefore contribute to optimum growth and performance of cool season grasses including orchardgrass. The effect of cooler

Table 18. Mean temperatures (C°), Obihiro, Japan, May–September, 1965–1969

Month	Mean temperature (Degrees C)						
	1965	1966	1967	1968	1969	5yr Ave	Amherst, Ma.[1]
May 1–10	7.5	9.9	13.1	11.4	11.5		
11–20	11.5	11.4	10.8	8.3	10.9		
21–31	12.4	11.3	12.7	9.8	8.3		
Average	10.5	10.9	12.2	9.8	10.1	10.7	14.0
June 1–10	12.4	10.1	12.8	13.3	12.0		
11–20	15.0	14.0	15.3	14.9	15.1		
21–30	17.7	14.3	16.1	17.1	17.7		
Average	15.0	12.8	14.7	15.1	15.0	14.5	16.7
July 1–10	15.2	13.9	15.8	15.4	15.4		
11–20	16.8	17.4	20.7	18.5	19.8		
21–31	18.0	18.1	21.4	22.7	21.6		
Average	16.7	16.5	19.4	18.9	19.0	18.1	21.7
Aug 1–10	19.3	17.7	22.0	22.5	18.3		
11–20	19.6	18.4	20.9	17.8	17.9		
21–31	20.2	22.1	19.3	17.2	18.3		
Average	19.7	19.5	20.7	19.2	18.2	19.5	20.3
Sept 1–10	16.3	17.5	18.6	14.8	18.7		
11–20	16.0	13.6	13.1	16.4	16.3		
21–30	14.0	13.0	12.7	14.8	11.1		
Average	15.5	14.7	14.8	15.3	15.4	15.1	16.1

1) Climatological data, a seventy year summary 1889–1958, Mass. Agr. Exp. Sta. Bul. 511, 1959.

growing temperatures on Ladino clover and alfalfa would, if anything, tend to reduce any competitive advantage they might have over the grasses.

Precipitation data shown in Table 19 again show significant differences between Obihiro and Amherst. Over the five months growing period the monthly average rainfall at Amherst is fairly constant at 100 mm or a little less per month. At Obihiro monthly rainfall tends to increase each month beginning in May and extending through September. The exception shown for July of 77.8 mm results from two dry July years in 1968 and 1969. A long time average value would undoubtedly reduce if not eliminate this discrepancy.

Increasing monthly rainfall rates during the growing season would be ideal for perennial forage crops because as the weather warms up and growth rates increase, the need for moisture increases also. It would especially favor shallow rooted Ladino clover and would improve its competitive status with a companion cool season grass. One would not expect a substantial effect on a deep rooted legume like alfalfa.

Table 19. Precipitation (mm), Obihiro, Japan, May–September,1965–1969

Month	Precipitation (mm)						
	1965	1966	1967	1968	1969	5yr Ave	Amherst, Ma.
May 1–10	22.1	44.8	1.9	27.8	14.0		
11–20	12.6	13.7	46.2	55.5	12.5		
21–31	13.8	8.5	0.0	56.0	77.0		
Total	48.5	67.0	48.1	139.3	103.5	81.3	94.2
June 1–10	58.6	10.1	136.4	7.0	58.0		
11–20	0.0	10.2	10.8	19.0	25.0		
21–30	15.6	112.8	38.1	10.0	35.0		
Total	74.2	133.1	185.3	36.0	118.0	109.5	90.7
July 1–10	25.0	23.8	61.8	10.0	13.0		
11–20	54.0	26.3	22.6	34.0	11.0		
21–31	20.5	39.3	28.5	3.0	16.0		
Total	99.5	89.4	112.9	47.0	40.0	77.8	100.5
Aug 1–10	20.0	34.1	29.4	24.0	61.0		
11–20	2.9	55.9	11.5	31.0	51.0		
21–31	8.2	6.9	33.6	99.0	101.0		
Total	31.1	96.9	74.5	154.0	213.0	114.9	97.5
Sept 1–10	143.3	75.8	20.4	28.5	32.0		
11–20	115.0	7.4	82.1	5.5	7.0		
21–30	15.3	78.6	72.5	33.0	8.5		
Total	273.6	161.8	175.0	67.0	47.5	145.0	99.7

For the two weather factors discussed, average temperature and monthly precipitation, the situation at Obihiro is more favorable to optimum growth and performance of grasses and to some extent Ladino clover than at Amherst. There is little indication why the legumes, Ladino clover and alfalfa, persist so much longer and are more productive at Obihiro. Table 20, on the other hand, showing hours of sunshin may provide some useful information. There are many fewer hours of sunshine at Obihiro than at Amherst. In May the percentage of sunshine compared to Amherst is 78 per cent, in June 66, in July 57, in August 51, and in September 76 percent. The significance of these substantial differences in hours of sunshine has been interpreted by the late Dr. George N. HOFFER[1] in a private communication to Dr. DRAKE. Dr. HOFFER believed that the short flat leaflets of the legumes held mostly in a position of 90° or near 90° to the light rays would absorb more energy than the long drooping leaves of grasses, especially as plant height increases. This greater efficiency of light absorption by the legumes over the grasses would give the legumes a greater competitive advantage and therefore explain to some extent at least why Ladino clover and

1) Dr. George N. HOFFER, Botanist Purdue University, and later staff member of American Potash Institute.

Table 20. Hours of sunshine, Obihiro, Japan, May–September, 1965–1969

Month	Hours of sunshine						
	1965	1966	1967	1968	1969	5yr Ave	Amherst, Ma.
May 1–10	50.0	81.3	66.9	71.8	76.9		
11–20	81.4	77.3	35.6	26.1	81.9		
21–31	99.0	88.4	75.8	19.5	50.7		
Total	230.4	247.0	178.3	117.4	209.3	195.0	250.1
June 1–10	58.3	37.2	39.0	67.2	71.2		
11–20	59.3	80.2	66.3	69.9	62.9		
21–30	79.6	37.6	65.2	76.2	71.1		
Total	197.2	155.0	107.5	213.3	205.2	173.6	261.3
July 1–10	66.6	42.4	37.1	56.0	58.6		
11–20	36.2	51.1	49.1	40.8	58.7		
21–31	52.5	52.6	36.7	66.9	62.1		
Total	155.3	146.1	142.9	163.7	179.4	157.5	274.9
Aug 1–10	37.2	13.8	61.4	41.9	32.1		
11–20	34.0	5.5	50.2	27.8	31.9		
21–31	70.7	73.2	48.8	56.6	41.0		
Total	141.9	92.5	160.4	126.3	105.0	125.2	244.0
Sept 1–10	17.9	67.5	52.9	39.7	65.2		
11–20	54.1	62.0	5.4	51.8	75.9		
21–30	65.4	54.8	37.7	41.9	83.1		
Total	137.4	184.3	96.0	133.4	244.2	155.1	204.8

alfalfa when adequately fertilized and properly managed as shown in these experiments can be so productive over a ten year period.

Snow cover is the last point of difference to be mentioned. Ordinarily most of Hokkaido receives a heavy snowfall. Melting snow into the spring is the principle reason for slow spring growth. The snow cover at Amherst is highly variable. In certain years it may be heavy; in others, light. A heavy snow cover is excellent protection against low temperature injury and is also excellent protection against injury from strong cold desiccating winds. The thick fleshy stolons ofLadino clover are particularly susceptible to this type of injury.

Summary of 1965–1969 Yields

In 1969, the phosphorus content of both alfalfa and Ladino clover and the associated orchardgrass fell to dangerously low levels. These low P levels threaten the stand longevity as well as indicate substandard levels of P for animal nutrition. Where alfalfa or Ladino clover in association with a vigorous grass such as orchardgrass is to be grown more than 5 years, 2000 kg of super

phosphate/ha should be banded at planting.

Application of 83 kg/ha of potassium as KCl after each cutting was highly effective in maintaining both yields and a desirable proportion of either alfalfa or Ladino clover in the mixture with orchardgrass. However, this 83 kg/ha rate of K application did not equal the total K removal by alfalfa-orchardgrass in the second five year period (1250 added and 1572 removed) and by Ladino clover-orchardgrass (1250 added and 1563 removed). The application of 167 kg/ha after each cutting exceeded K removal (2500 applied–1693 removed alfalfa-orchardgrass and 2500–1657 Ladino clover-orchardgrass). Thus 100 to 120 kg K/ha after each cutting appears to be required under the conditions of this experiment for this soil.

The per cent K declined each year in alfalfa (1.71, 1.68, 1.50) and Ladino clover (1.74, 1.71, 1.44), respectively, in 1965, 1967 and 1969 when no fertilizer K was added annually. When 83 kg K/ha were applied after each cutting, alfalfa ranged from 3.70 to 3.94, Ladino clover from 3.21 to 3.99 and orchardgrass from 3.91 to 4.23 per cent K. With 167 kg K after each cutting alfalfa ranged from 3.87 to 4.05, Ladino clover 3.73 to 4.14 and orchardgrass 3.97 to 4.34 per cent K. Based on the first five year study, recommended levels of K were: Ladino clover 3.5; alfalfa 3.0 to 3.5, and orchardgrass 3.5 to 4.0 per cent K. Under conditions of this research, the application of 83 kg K/ha after each cutting maintained a favorable level of K in these forage species. However, this 83 kg rate of K did not equal K removed in the forage.

Alfalfa from plots without fertilizer K contributed only 5 to 9 per cent of the alfalfa-orchardgrass dry matter yield. Alfalfa contributed 33 to 50 per cent of the yield of alfalfa-orchardgrass when fertilizer K was applied after each cutting. Ladino clover without annual K contributed only 9 to 12 per cent of the dry matter yield of Ladino clover-orchardgrass as compared to 22 to 35 per cent with fertilizer K.

Nitrogen level in forage of the alfalfa-orchardgrass and of the Ladino clover-orchardgrass mixtures was increased greatly when desirable legume to grass ratios were maintained by fertilizer K. Dry matter yields were more than doubled; nitrogen was increased from 2.30 (low K) to over 3.00 per cent in the forage; and total N production was almost tripled.

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摘　　要

生育6-10年次 (1965-1969) の5年間における加里追肥がアルファルファ・オーチャードグラスおよびラデノクローバ・オーチャードグラス混播の乾物生産，N・P および K 含量に及ぼす影響について研究を行なった結果を摘要すると次のごとくである。

1. 生育10年次の1969年には両混播におけるアルファルファおよびラデノクローバ，オーチャードグラスの P 含量は急激に低下し，K 無追肥では限界値の0.13%に達した。この P の低含量は植生の存続性にはもちろん，家畜の栄養にも障害を起こす脅威を与えるものと考えられる。したがって，生育旺盛なオーチャードグラスとアルファルファまたはラデノクローバとの混播草地の植生を5年以上存続せしめるには，播種時に ha あたり 400 kg くらいの燐酸

質肥料を帯状に施用すべきであろう。

2. オーチャードグラスとアルファルファまたはラデノクローバ混播においては，各刈り取り後 ha あたり 83 kg の KCl を施用することは乾物生産を高める上にも，混播した植生のマメ科率を高める上にも効果的であった。しかし，1965–1969 年の 5 カ年間に毎年 ha あたり 250 kg K を施用すると，アルファルファ・オーチャードグラス混播では 1250 kg の K 施用量となるが，吸収された量は 1572 kg であり，施用量に比し多かった。また，500 kg K/ha を施用すると 2500 kg となり，この場合の吸収量は 1693 kg であって施用量に比し少なかった。ラデノクローバ・オーチャードグラス混播では，それぞれ 1250 kg の施用量では吸収量が 1563 kg となり，2500 kg の施用量では吸収量は 1657 kg となった。したがって，この草地土壌条件では各刈り取り後に 100–120 kg K/ha を施用することがのぞましいであろう

3. 混播草地における K 含量は K，無追肥では 1965 年のアルファルファで 1.71%，ラデノクローバで 1.74%，1967 年の場合それぞれ 1.68%，1.71%，1969年の場合それぞれ 1.50%，1.44%であった。

これに対して毎年，各刈り取り後 83 kg K/ha 追肥したものはアルファルファで 3.70–3.94%，ラデノクローバで 3.21–3.99%，オーチャードグラスで 3.91–4.23%であった。さらに毎年，各刈り取り後 167 kg K/ha 追肥したものはそれぞれアルファルファで 3.87–4.05%，ラデノクローバで 3.73–4.14%，オーチャードグラスで 3.97–4.34%となった。この結果からみるとおおむね毎年，各刈り取り後 83 kg K/ha の施用を行なうときは K 収支では負となるが，草種に適当な K 含量を維持せしめる量であろうと考えられた。

4. マメ科率を混播の総乾物量に対してマメ科草によって占められている乾物量の割合で比較すると，K 無追肥ではアルファルファ・オーチャードグラス混播で 5–9%であったが，追肥を行なった場合は 33–55%となった。また，ラデノクローバ・オーチャードグラス混播でそれぞれ 9–12%，22–35%となった。

5. N 含量も K 追肥によって高くなったが，これは K 追肥によってマメ科率が高くなったことと根粒菌の活性が強化されたことによるものであろう。つまり N 含量と乾物量の増加によって N 生産量はほぼ 3 倍にも達した。

以上のごとく，イネ科牧草とマメ科牧草との混播では基肥として初期生育のための P の施用と K の追肥が乾物生産にはもちろん，N・P・K 含量とその成分生産量を高める上にも効果的であった。

Photo 1. Alfalfa-orchardgrass mixture without topdressing of K, June 17, 1972

Photo 2. Alfalfa-orchardgrass mixture with topdressing of 300 kg K_2O/ha, June 17, 1972

Photo 3. Ladino clover-orchardgrass mixture without topdressing of K, June 17, 1972

Photo 4. Ladino clover-orchardgrass mixture with topdressing of 300 kg K_2O/ha, June 17, 1972