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The Equilibrium between available Nutrients in the Soil and Plants Nutrients absorbed by Forage with some Fertilization on different Soils for Five Years

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Introduction

For over 100 years, plant physiologists have been studying the mineral nutrition of plants. Extensive investigations have been carried out to determine which elements are essential, how the plant absorbs them, how they are utilized, why they are essential, and what effects are produced in the plant when a particular essential element is lacking[1].

Plants utilize elements in four basic ways: (a) The elements may form part of structure units, such as carbon in cellulose or nitrigen in protein. (b) Elements may be incorporated into organic molecules important in metabolism, like magnesium in chlorophyll or phosphorus in ATP. (c) Elements may function as enzyme activators, necessary as catalysts in certain enzymatic reactions. Magnesium is used as an enzyme activator in several of the enzymatic steps of glucose degradation in the process of respiration. (d) Elements in ions help to maintain the osmotic balance, for example, potassium in guard cells[2].

The elements recognized as essential to the continued growth and development of green plants are the following 16 elements, with their apporopriate chemical symbols: carbon (C), hydrogen (H), oxygen (O), phosphorus (P), potassium (K), nitrogen (N), sulfur (S), calcium (Ca), magnesium (Mg), iron (Fe), boron (B), molybdenum (Mo), manganese (Mn), zinc (Zn), copper (Cu), and chlorine (Cl).

Table 1 shows the relative amounts and concentration of macro- and micronutrients absorbed by alfalfa, orchadgrass, and smooth bromegrass during a growing season[3,4].

Certain other elements are required by some plants in very small amounts. Sodium, for example, is required in very small amounts by such C_4 plants as the desert shrub Atriplex, but is not required by most other species. It is generally not considered an essential element for most higher green plants. However, it is likely that not all of the elements essential for plant growth have get been identified. For example, there is recent evidence that silicon may be essential for the growth of at least some plants.

A plant growing in soil or in solution cannot distiguish between elements

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Table 1. Amounts and concentrations of macro and micro nutrients absorbed by alfalfa and orchardgrass or smooth bromegrass for the soils in the growing season[3)4)]

		Macro nutrients						Micro nutrients							Mineral nutrients for the Mammalia				
Elements		N	P	K	Ca	Mg	S	Fe	B	Mo	Mn	Zn	Cu	Cl	Na	Co	Se	F	I
		(*kg ha^{-1} year^{-1}) (**per cent, dry matter basis)							(*3 g ha^{-1} year^{-1}) (*4 ppm)							(*5 g ha^{-1}year^{-1} (*6 ppb)			
Alfalfa	Amounts	*290	28	261	110	18	38	*3 1387 11)	272	1.8	335	254	54	—	*1.0	*5 0.21	0.05	—	0.46
	Concentration	**3.20	0.31	2.88	12.1	0.20	0.42	*4 153	30	0.2	37	28	7	—	**0.11	*6 230	46	—	380
Orchardgrass	Amounts	228	32	336	33	19	38	368	53	1.1	759	242	63	—	1.3	0.19	0.03	—	3.78
	Concentration	2.17	0.30	3.20	0.31	0.18	0.36	35	5	0.1	72	23	6	—	0.12	180	35	—	3596
Smooth bromegrass	Amounts	225	25	228	31	19	12	402	30	1.0	763	171	80	—	1.2	0.05	0.04	—	—
	Concentration	2.24	0.25	2.27	0.31	0.19	0.12	40	3	0.1	76	17	8	—	0.12	50	40	—	—

The yields of Alfalfa, orchardgrass and smooth bromegrass were 9,063, 10,510, and 10,050 kg ha^{-1}year^{-1} respectively on Nopporo diluvial soil.

that are essential to it and those that are not essential or that might be harmful. If the element or ion containing it is in solution, it will probably be absorbed by the plant. Thus, we find in the plant almost all the elements present in the soil.

We reported that the absorptions of some cations and anions by alfalfa and orchardgrass from soils or cultures solutions were effected with those ion contents in the soil or culture solution. We reported also, that those ions adsorbed were related to homologous series of ions[5], the relationship being a negative correlation among those cations or anions[6].

In the present paper, we report the relationships between the nutrients absorbed from the soils and the growth habit of alfalfa and orchardgrass or smooth bromegrass with some fertilization on different soils. The studies were conducted on the cold area in Hokkaido, Japan.

Materials and Methods

The studies were carried out on fields in Hokkaido, Japan. The experiments were divided three parts for the purpose. The soils used were Nopporo diluvial, Uenae pumice volcanic, Shinotsu alluvial, and Bibai peat soil in Hokkaido, Japan, for the first experiment. In the second experiment, Eniwa volcanic soil was used, and in the third experiment, Nopporo diluvial soil was used. The chemical characteristics of the soils prior to the initation of the experiment are shown in Table 2. The Nopporo diluvial soil had pH (H_2O) 6.0 and (KCl) 4.9. The content of total nitrogen was 0. 39 per cent, and available phosphorus was a lower content of 0.3 mg/100 g dry soil. The content of exchangeable potassium was a

Table 2. Chemical characteristics of soils used

Soil	pH		EC	Total-N	Available-P	Exchangeable				Trace element				Mineral nutrients for the Mammalia in the soils			
	H_2O	KCl	mS/cm	(%)	(mg/100 g dry soil)	K	Na	Ca	Mg	Zn	Mn	Cu	B	*Co[10]	**Se	F	I
						(mg/100 g dry soil)				(0.1 N HCl extractable)			(hot water extractable)	*Dissolved with HF			
Nopporo Diluvial soil	6.0	4.9	88	0.39	0.3	4.6	4.1	136	10.3	3.0	22.0	0.7	0.26	33.6	0.63	—	5.3
Uenae Pumice volcanic soil	6.3	5.5	74	0.12	8.1	3.3	2.2	43	3.6	2.9	23.9	4.0	0.62	55.3	0.14	—	1.6
Shinotsu Alluvial soil	6.4	5.1	57	0.23	3.2	8.2	4.7	211	36.0	5.8	25.4	4.5	1.02	37.1	0.29	—	2.1
Bibai Peat soil	3.9	2.9	393	1.90	0.8	11.4	17.2	36	4.8	8.4	9.4	0.5	2.70	8.8	0.19	—	13.5
Eniwa Volcanic soil	5.8	4.8	—	0.22	0.3	8.0	2.5	166	5.6	4.9	71.3	3.5	—				

** Dissolved with HNO_3 and $HClO_4$

lower values of 4.6 mg/100 g dry soil. The soluble (0.1 N HCl) Zn, Mn, and Cu contents were 3.0, 22.0, and 0.7 mg/100 g dry soil respectively. The Uenae pumice volcanic soil had pH (H_2O) 6.3 and (KCl) 5.5. The content of total nitrogen was a low 0.12 per cent, and phosphorus was 8.6 mg/100 g dry soil. The contents of exchangeable potassium, calcium and magnesium were each lower values of 3.4, 43, and 3.6 mg/100 g dry soil, respectively. The soluble Zn, Mn, and Cu contents were 2.9, 23.9, and 4.0 mg/100 g dry soil, respectively. The Shinotsu alluvial soil had pH (H_2O) 6.4 (KCl) 5.1. The contents of exchangeable potassium, calcium, and magnesium were the high values of 8.2, 4.7, and 36.0 mg/100 g dry soil, respectively. The Bibai peat soil had pH (H_2O) 3.9 and (KCl) 2.9. The content of total nitrogen was a higher values 1.90 per cent, and available phosphorus was lower of 0.9 mg/100 g dry soil. The Eniwa soil had pH (H_2O) 5.8 and (KCl) 4.8. The available phosphorus was a lower values of 0.3 mg/100 g dry soil. The contents of exchangeable pottassium, calcium, and magnesium were 8.0, 166, and 5.6 mg/100 g dry soil, respectively.

In the first experiment, alfalfa (*Medicago sativa* L.) and orchardgrass (*Dactylis glomerata* L.) were grown on these soils with eight different fertilizations, namely; 1) barnyard manure and NPK (BM-NPK), 2) NPK (NPK), 3) PK (-N), 4) NK (-P), 5) NP (-K), 6) NPK with sulphur (NPK with S), 7) NPK with chlorin (NPK with Cl), and 8) cotrol (nil fertilizer) (-F). The amounts of basic fertilizers used are shown in Table 3. The treatment period was five years.

Table 3. Amounts of basic fertilizer used for first experiment

Nutrient and rate	Source of nutrient kg $ha^{-1}year^{-1}$
Nitrogen	125 as N urea $(NH_2)_2CO$ or as Ammonium sulphate $(NH_4)_2SO_4$ or Ammonium chloride (NH_4Cl)
Phosphate	200 as P_2O_5 Ammonium phosphate $[(NH_4)_2HPO]$ or Super phosphate $CaH_4(PO_4)_2$
Potassium	250 as K_2O potassium sulphase (K_2SO_4) or potassium chloride (KCl)
Barnyard manure	30 t as Dairy cattle Barnyard

Both alfalfa and orchardgrass were harvested at firstflower stage of alfalfa. The herbage and soils were analyzed for elements of nutrients and selenium. Determinations of selenium in the soils and plants were carried out at 378 nm of excited wavelength and 250 nm of fluoresence wavelength using Hitachi 650-10S fluoresence spectrophotometer.

The size of each plot was 10 m^2, and the experimental design was a block with three replicates.

In the second experiment, alfalfa (cultiver Vertus) and smooth bromegrass (cultiver Saratoga) were grown on Eniwa volcanic soil, and the field used was paddy soil on which rice was cultivated for 20 years. The fertilizer system were 1) barnyard manure with chemical fertilizers plot (BMF-plot), and 2) non-barnyard

Table 4. Amounts of fertilizer for five years for second experiment

Basic fertilizer

Kind of fertilizer	Amount of fertilizer
Barnyard manure	30,000 kg ha^{-1}
Fused magnesium	1,500 kg ha^{-1}
calcium carbonate	340 kg ha^{-1}

additional fertilizer

Kind of fertilizer	1st	2nd	3rd	4th	5th year	Total
Barnyard manure	30 t ha^{-1}					30 t
Fused magnesium	1,500*	—	1,500	1,000	1,450	3,950
potassium sulphase	—	400	900	900	300	2,500
FTE (Trace element)	—	—	4	4	4	12
Superphosphate	—	500	—	—	—	500

* kg ha^{-1}

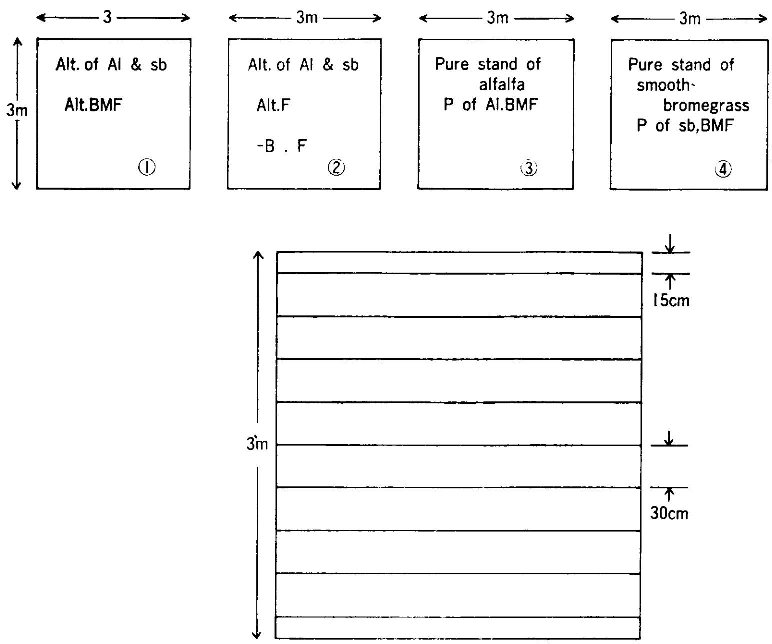

Fig. 1. Plan of plots for second experiment.

① Alternate stand of alfalfa and smooth bromegrass with barnyard manure and chemical fertilizer (Alt. BMF)

② Alternate stand of alfalfa and smooth bromegrass with chemical fertilizer (Alt. F)

③ Pure stand of alfalfa with barnyard manure and chemical fertilizer (P of Al. BMF)

④ Pure stand of smooth bromegrass with barnyard manure and chemical fertilizer (P of Sb, BMF)

Table 5. Amounts of fertilizer for third experiment

a. Basic Fertilizers

Type of fertilizer	g/m^2	g/m^2
Super phosphate	10	2 as P_2O_5
Potassium sulfate	40	20 K_2O
Calcium carbonate	60	336 CaO
Fused magnesium	20	3 MgO

b. Amounts of Nitrogen Fertilizers

Type of Nitrogen	Chemical formula	Amount of N g/m^2
Ammonium chloride	NH_4Cl	
Ammonium sulfate	$(NH_4)_2SO_4$	0, 5, 10, 20 and 40 as N
Ammonium nitrate	NH_4NO_3	

manure with chemical fertilizer plot (F-plot). The amounts of fertilizer applied were added to keep a level of 10 mg/100 g dry soil of available phosphorus, 0.64 (25 mg) of exchangable potassium, 7.0 (140 mg) of calcium, and 1.5 meq. (18 mg) 100 g of magnesium, respectively, as shown in Table 4 and Fig. 1. Alfalfa or smooth bromegrass was sowed in by single in each row or alternate rows. The soil samples were taken from a depth of 10 cm every year after cutting, and were analyzed. The forage were harvested also, and analyzed for nutrients of the plants.

The amount of basic fertilizers applied to the plots in the third experiment, are shown in Table 5. The fertilization was done using chemical fertilizer. The size of each plot was 1 m^2, and the experimental design was a block with three replicates. Alfalfa (cultivar Vertus) and smooth bromegrass (cultivar Saratoga) were grown no Nopporo diluvial soil with the same basic fertilizer, to which were added five levels of three nitrogen compounds, that is 0, 5, 10, 20, and 40 g/m^2 as N of ammonium chloride, ammonium sulfate, and ammonium nitrate, respectively.

Both plants were harvested at first-flower stage of alfalfa. After the first cutting, amounts of 1/2 basic nitrogen compounds were applied to each plot, and both regrowth plants were sampled as weeks 1, 2, 5, and 7. The herbage and soils were analyzed for nitrite, nitrate, and total nitrogen. The determination of anions in the plant and the soil was carried out using Dionex ion chromatography.

Results and Discussion

First exsperiment;

Forage yield

The forage yield per ha for five years was related to the soil types and the fertilizer treatments. The highest forage yield on average for alfalfa was obtained

Table 6. Dry matter yield of forage for first experiment

* (t ha⁻¹ 5 years⁻¹)

Treatment of fertilization	Alluvial soil		Volcanic soil		Peat soil		Diluvial soil		Average		Rate by treatment of fertilization	
	Al	Og	Al	Og	Al	Og	Al	Og	Al	Og	Al	Og
Barnyard and complete fertilizer (BM-NPK)	*39.1	*54.5	34.1	40.4	34.5	45.0	43.3	47.3	37.8	46.9	100	100
Complete fertilizer (NPK)	40.9	51.8	31.9	36.8	29.1	39.4	40.6	43.7	35.6	42.9	94	92
Sulfure-system ferti. (NPK with S)	40.9	52.1	32.4	37.8	28.5	43.4	36.9	43.5	34.7	44.2	92	94
Chlorine-system ferti. (NPK with Cl)	35.6	50.5	30.9	33.3	29.0	35.7	24.5	37.2	32.5	39.2	79	84
Non-nitrogen (-N)	37.7	35.1	30.8	14.5	27.1	25.3	35.2	17.9	32.7	23.2	87	50
Non-phosphate (-P)	37.8	49.5	27.6	33.0	4.8	9.5	30.3	20.5	25.1	28.1	66	60
Non-potassium (-K)	36.2	44.6	27.0	21.8	7.7	14.2	26.1	22.1	24.3	25.7	64	55
Non-fertilizer (-F)	37.9	34.7	13.4	18.8	0	0	13.7	13.2	16.3	12.5	43	27
Average	38.3	46.6	28.5	29.6	20.1	26.6	31.3	30.7	29.9	33.8	79	70
Ratio by soil	100	100	74	63	52	57	81	65	78	72		

Al: Alfalfa Og: Orchardgrass

on the Nopporo diluvial soil with barnyard manure and complete fertilizer (BM-NPK) and for orchardgrass on Shinotsu alluvial soil with barnyard manure and complete fertilizer (BM-NPK). The amounts of forage were 43.3 t/ha/5 years for alfalfa and 54.5 t/ha/5 years for orchardgrass. The lowest yield for alfalfa and orchardgrass was obtained on Bibai peat soil with non-fertilizer (-F). The amounts of both plants were either. Those results are shown in Table 6. The ratio of forage yield between barnyard manure with complete fertilizer plot and non-nitrogen fertilizer plot (-N plot) was 100 : 87 for alfalfa, and the range was from 96.4 on Shinotsu alluvial soil to 76.6 on Bibai peat soil. The ratio of non-phosphate plot (-P plot) was 66 for alfalfa and 60 for orchardgrass, and the range for alfalfa was from 96.7 on Shinotsu alluvial soil to 13.9 on Bibai peat soil. The ratio of non-potassium plot for alfalfa was 64 and orchardgrass 55. The range for alfalfa was from 92.6 on alluvial soil to 22.3 on peat soil.

The ratio of forage yield on barnyard manure with complete fertilizer plot, complete fertilizer with sulfur, and complete fertilizer with chlorine was 100 : 94 : 92 for alfalfa, and 100 : 92 : 94 for orchardgrass. The range for alfalfa was from 104.6 on allivial soil with complete sulphur fertilizer to 82.6 on peat soil with complete sulphur fertilizer. The range for alfalfa was from 91.0 on alluvial soil with complete chlorine fertilizer to 84.4 on peat soil with same fertilizer. On the other hand, for orchardgrass, the range was from 96.2 on peat soil with sulphur fertilizer to 92.0 on the diluvial soil with the same fertilizer and from 92.7 on alluvial soil with chlorine fertilizer to 78.7 on diluvial soil with the same fertilizer.

The concentrations of nutrients in both plants grown in different fertilizations and soils

Macro nutrient

The concentrations of macro nutrients in alfalfa and orchardgrass were shown in Table 7, that is, the nitrogen concentration of alfalfa plant was 3.25±0.10 on the average, and of orchardgrass was 2.28±0.28 per cent on the average. The range of nitrogen concentrations of alfalfa was from 3.42 on non-potassium fertilizer plot (-K plot) to 3.12 on non-nitrogen plot (-N plot), and orchardgrass was from 2.36 on NPK with chloride plot to 2.08 per cent on non-nitrogen fertilizer plot (-N plot). The phosphate concentration of alfalfa was 0.24±0.15 on the average, and of orchardgrass was 0.31±0.26 per cent. The range of phosphate concentration of alfalfa was from 0.28 on non nitrogen fertilizer plot (-N plot) to 0.18 on non-phosphate fertilizer plot (-P plot) except for non-fertilizer plot, and that of orchargrass was from 0.40 on non-nitrogen fertilizer plot (-F plot) to 0.21 per cent on non-phosphate plot (-P plot). The potassium concentration of alfalfa was 2.45±0.88, and that of orchardgrass was 2.71±0.98 per cent. The range of potassium concentration of alfalfa was from 3.03 on barnyard manure with

Table 7. Concentration of macro-nutrients in plants grown with different fertilization for first experiment (% as element, dry matter basis)

		-F n=39	BM-NPK n=53	NPK n=53	-N n=53	-P n=53	-K n=53	NPK with S n=53	NPK with Cl	Average S. D.
N	Alfalfa	3.14 ±1.34	3.24 ±0.48	3.22 ±0.48	3.12 ±0.52	3.32 ±0.48	3.42 ±0.42	3.20 ±0.54	3.33 ±0.45	3.25 ±0.10
	Orchard-glass	1.76 ±1.09	n=52 2.27* ±0.45	2.20 ±0.69	2.08 ±0.57	2.58 ±0.72	2.76 ±0.65	2.28 ±0.63	2.36 ±0.66	2.28 ±0.28
P	Alfalfa	n=42 0.17 ±0.11	n=53 0.27 ±0.23	0.26 ±0.16	0.28 ±0.14	0.18 ±0.09	0.27 ±0.12	0.26 ±0.14	0.24 ±0.14	0.24 ±0.15
	Orchard-glass	0.24 ±0.18	0.36 ±0.33	0.36 ±0.34	0.40 ±0.19	0.21 ±0.11	0.30 ±0.14	0.35 ±0.33	0.31 ±0.26	0.31 ±0.26
K	Alfalfa	n=39 1.91 ±0.59	3.03 ±0.65	2.74 ±0.66	2.73 ±0.61	2.68 ±0.55	1.51 ±0.79	2.74 ±0.55	2.72 ±0.64	2.45 ±0.88
	Orchard-glass	1.88 ±1.12	3.32 ±0.54	2.93 ±0.69	2.95 ±0.52	3.05 ±0.55	1.36 ±0.98	2.90 ±0.51	3.20 ±0.66	2.71 ±0.98
Ca	Alfalfa	n=42 1.07 ±0.74	1.28 ±0.51	1.31 ±0.53	1.31 ±0.50	1.29 ±0.32	1.62 ±0.44	1.31 ±0.55	1.33 ±0.45	13.1 ±0.14
	Orchard-glass	0.25 ±0.19	0.36 ±0.25	0.35 ±0.19	0.33 ±0.12	0.32 ±0.16	0.40 ±0.18	0.36 ±0.26	0.33 ±0.20	0.33 ±0.04
Mg	Alfalfa	n=42 0.19 ±0.13	0.20 ±0.09	0.22 ±0.10	0.23 ±0.10	0.20 ±0.07	0.35 ±0.18	0.23 ±0.10	0.23 ±0.09	0.23 ±0.12
	Orchard-glass	0.17 ±0.12	0.20 ±0.15	0.20 ±0.11	0.19 ±0.10	0.20 ±0.07	0.26 ±0.09	0.20 ±0.13	0.22 ±0.10	0.20 ±0.11

complete fertilizer plot (BM-NPK plot) to 1.51 on non-potassium plot (-K plot), and that of orchardgrass was from 3.32 on BK-NPK plot to 1.36 per cent on -K plot. The calcium concentration of alfalfa was 1.31±0.14, and that of orchardgrass was 0.33±0.04 per cent. The range of calcium concentration of alfalfa was from 1.62 on potassium fertilizer plot (-K plot) to 1.07 on non-fertilizer plot (-F plot), and that of orchardgrass, was from 0.40 on non-potassium plot (-K plot) to 0.25 per cent non fertilizer plot (-F plot). The magnesium concentration also of alfalfa was 0.23±0.12, and of orchardgrass was 0.20±0.11 per cent. The range of magnesium concentration of alfalfa was from 0.35 on non-potassium fertilizer plot (-K plot) to 0.19 on non-fertilizer plot (-F plot), and that orchardgrass was from 0.26 on non-potassium fertilizer plot (-K plot) to 0.17 per cent on non-fertilizer plot (-F plot).

Other topics of macro nutrients of both plants

1) The nitrogen concentration of alfalfa plants ranged from 3.43 to 3.08 per cent depending on the kind of soil, fertilizers, and cutting time. On the other hand, that of orchardgrass was lower than that of alfalfa, from 2.76 to 1.76 per cent, and the nitrogen yield in -N plot was 74-97 per cent of all plots, except in -N plot of alfalfa on 4 soil for five years[7]. 2) The phosphate concentration of both plants increased from first year herbage to 5th year herbage, and there was no difference in the kind of soil and the cutting time. 3) The potassium concentrations of both plants were lower on non-potassium fertilizer plot than on complete

Table 8. Concentration of micro nutrients in plants grown with different fertilization (ppm dry matter basis) for first experiment

a. Manganese * n=55

		-F n=42	BM-NPK	NPK	-N	-P n=56	-K	NPK with S	NPK with Cl	Average LSD
Mn	Alfalfa	35.84 ±16.65	38.03 ±16.46	35.94 ±19.71	36.74 ±21.20	30.60 ±16.34	39.87 ±25.71	46.73 ±22.06	49.21 ±24.92	39.12 ±5.71
	Orchard-grass	78.07 ±20.70	71.89 ±47.40	65.94* ±36.22	72.76 ±40.90	56.85 ±35.77	66.26 ±35.36	100.94 ±47.03	94.75 ±53.18	75.93 ±14.00

b. Zinc

Zn	Alfalfa	30.45	27.15	26.42	25.72	31.10	27.55	28.81	29.01	28.28 ±1.78
	Orchard-grass	24.78	23.16	21.30	21.26	23.33	23.80	23.78	22.19	22.95 ±1.18

c. Copper

Cu	Alfalfa	9.50 ±3.09	6.65 ±2.32	66.8 ±2.69	6.48 ±2.43	9.18 ±3.49	6.84 ±2.41	7.01 ±3.17	7.61 ±3.21	7.49 ±1.11
	Orchard-grass	7.77 ±2.68	6.02 ±2.39	6.34 ±2.29	6.34 ±2.08	7.51 ±2.37	6.48 ±2.28	6.53 ±2.50	6.98* ±3.28	6.75 ±0.58

fertilizer plot; 1.51 per cent for alfalfa and 1.36 per cent for orchardgrass. 4) The calcium concentration of alfalfa was always higher than that of orchardgrass. 5) The magnesium concentration of alfalfa was 0.24-0.11 per cent and that of orchardgrass was 0.21-0.11 per cent. There is an interspecific difference of magnesium absorption for both plants.

Concentrations of micro nutrients in both plants

The concentrations of micro nutrients in alfalfa and orchardgrass are shown in Table 8. The manganese concentration of alfalfa was 39.12±5.71 on average, and that orchardgrass was 75.93±14.00 ppm. The range of manganese concenttation of alfalfa was from 49.21 on NPK with chloride plot (NPK with Cl plot) to 30.60 on non-phosphate plot (-P plot) and that of orchararardgrass, was from 100.94 on NPK with sulfur (NPK with S plot) to 56.85 ppm on non-phosphate plot (-P plot).

The concentration of zinc in alfalfa was 28.28±1.78 on average, and that in orchardgrass was 22.95±1.18 ppm on average. The range of zinc concentration in alfalfa was from 30.45 on non-fertilizer plot (-F plot) on 25.72 on non-nitrogen plot (-N plot), and that of orchardgrass was from 24.78 on non-fertilizer plot (-F plot) to 21.26 ppm on non-nitrogen plot (-N plot).

The concentration of copper in alfalfa grown on different soil was 7.49±1.11, and that in orchardgrass was 6.75±0.58 ppm on average. The range of copper concentration of alfalfa was from 6.48 on non-nitrogen plot (-N plot) to 9.50 ppm on non-fertilizer plot (-F plot), and that of orchardgrass was from 6.02 on barnyard manure with complete fertilizer (BM-NPK plot) to 7.77 ppm on non-fertilizer plot (-F plot).

Other topics of micro nutrients of both plants

1) The concentration of manganese in alfalfa grown with different fertilization was highest on NPK with chlorine plot (NPK with Cl plot) (49.21±24.92) and higher on NPK with sulfur plot (NPK with S plot) (46.73±22.06 ppm). In orchardgrass, the concentrations were 100.94 on NPK with sulfur plot (NPK with S plot) and 94.75 ppm on NPK with chlorine plot (NPK with Cl plot). For interspecific difference of manganese concentration on both plants, that of alfalfa was higher than that of orchardgrass. 2) Zinc concentrations absorbed by plants were 28.26 ±9.73 in alfalfa and 22.89±6.87 ppm in orchardgrass. Alfalfa was higher in zinc concentration than was orchardgrass, and interspecific difference of zinc absorption by plant was recognized. 3) The concentration of copper in both plants grown on different soils was lowest on peat soil; in alfalfa it was 4.35±3.19 and in orchardgrass 4.85±2.46 ppm. Alfalfa showed a higher uptake than orchardgrass, and the copper concentrations absorbed by alfalfa was 7.43±3.06, and by orchardgrass 6.69±2.55 ppm, but there were no significant differences between the two plants.

Contents of macro nutrients in the soils after treatments

The content of nitrogen was 0.63 per cent on average, and there were no significant differences between the two plants. The contents of available phosphate in the soils by different fertilization were 12.44±14.34 mg/100 g dry soil, and in soils on non-fertilizer and non-phosphate plots they were lower, 4.88 and 3.74 mg/100 g dry soil. The phosphate content also increased over time. The content of exchangeable potassium was 24.91±22.20 mg/100 g dry soil on average, and in the soils on non-fertilizer and non-potassium plot was low, 11.73 and 9.16 mg/100 g dry soil, respectively. The content of barnyard manure with NPK plot was high, 38.18 mg/100 g dry soil. The content of magnesium was 23.65±20.72 mg on average, and the difference of fertilizations and non-fertilizer plot was lower than that of other plots, and that of barnyard manure with NPK plot was higher than that of the others. The calcium content in the soil by fertilization was 277.8±271.6 mg/100 g dry soil on average, and that of non-fertilizer plot was lower than that of the other plots, 104.4, and the NPK with chlorine plot was also lower.

Content of micro nutrients in the soils after harvest

The contents of manganese, zinc, copper in the soils after harvest were 24.75 ±1.68, 1.56±0.12, and 8.24±1.56 ppm on average, respectively. But the differences by fertilizations was not significant. The contents of micro nutrients in the soils are shown in Table 9.

Table 9. Contents of micro nutrients in soils after cutting for first experiment

a. Manganese (ppm)

	-F	BM-NPK	NPK	-N	-P	-K	NPK with S	PK with Cl	Average
					n=40				
Mn	22.45 ±7.62	27.86 ±9.81	25.43 ±9.74	25.21 ±10.91	23.27 ±9.77	23.37 ±9.18	26.27 ±10.45	24.11 ±9.75	24.75 ±1.68

b. Zinc

Zn	10.5	9.95	5.44	8.47	6.40	8.39	8.18	8.56	8.24 ±1.56

c. Copper

Cu	1.32	1.56	1.67	1.70	1.49	1.54	1.48	1.69	1.56 ±0.12

Selenium contents in the soils and both plants

Selenium contents in the different soils and concentrations in alfalfa and orchardgrass grown on these soils are shown in Table 10 and Fig. 2. The values were significantly different in soils and also for both plant species. The highest content of selenium was found in the diluvial soils and the lowest in the pumice volcanic soil. The concentration of selenium in alfalfa plant was eight times as high as that in orchardgrass grown on the pumice volcanic soil.

According to NRC (1978), dairy cattle require about 0.1 ppm Se in there diet.

Table 10. Selenium contents in soils and selenium concentration in alfalfa orchardgrass

Soils	Selenium contents in the soils (ppm)	Selenium concentration (ppm) in alfalfa	in orchardgrass
Diluvial soil	0.626±0.130	0.043±0.006	0.037±0.007
Alluvial soil	0.293±0.079	0.061±0.031	0.036±0.016
Pumice volcanic soil	0.140±0.123	0.036±0.033	0.005±0.005
Peat soil	0.185±0.042	0.058±0.018	0.029±0.016

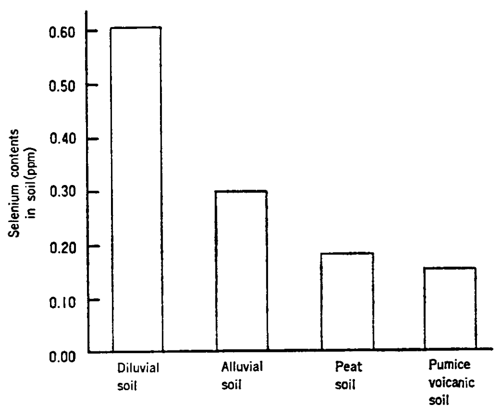

Fig. 2. Selenium contents in different soils.

The requirement is appreciably influenced by the chemical form of Se and the levels of interacting factors in the diet, including vitamin E, sulphur, lipids, proteins, amino acids, and several micro elements (Ammerman and Miller, 1975). Thus, the soils and the plants grown on the soils would affect the Se content and the performance of cattle[8,9].

Effect of fertilizers on Se concentration in plants

Selenium concentrations in alfalfa ranged from 0.11 ppm on non-fertilizer plots to less than 0.02 ppm in the non-nitrogen plots, with an average of 0.05±0.03 ppm. Selenium concentrations in orchardgrass ranged from 0.03 ppm in the non-fertilizer plots to 0.01 ppm in the non nitrogen plots, with an average of 0.02±0.06 ppm. These results (Fig. 3) show that the order of selenium concentration by fertilizer treatment was -F>NPK with Cl>-P>NPK>-K>BM-NPK>NPK with S>-N. This order suggests that selenium concentration in plants grown with fertilizers containing sulfur is low.

Relationship between selenium concentrations in the plants and amounts of sulfur added to the soils

The relationship between selenium concentrations in the plants and amounts of sulfur added to the soils are shown in Fig. 3 and 4. The addition of sulfur to the soils decreased selenium concentration of alfalfa and orchardgrass, that is

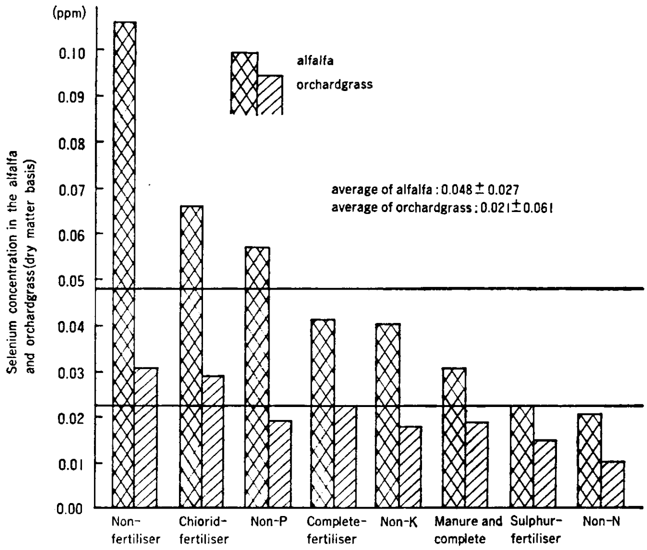

Fig. 3. Selenium concentration in alfalfa and orchardgrass.

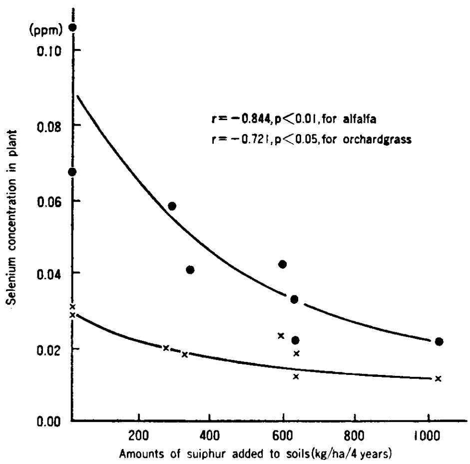

Fig. 4. Relationship between selenium concentration in plants and amount of sulfur added to soil.

negatively correlated. The coefficients of correlation were r = −0.884 for alfalfa and r = −0.721 for orchardgrass.

Relationship between sulfur and selenium concentration in plants

The evidence presented here shows that selenium competed with sulfur in the plant. The relationship between sulfur and selenium is shown in Fig. 5. The increase of sulfur concentration in the alfalfa decreased selenium concentration in the plant with coefficient of correlation of r = −0.993. Significant correlation was not obtained for the orchardgrass.

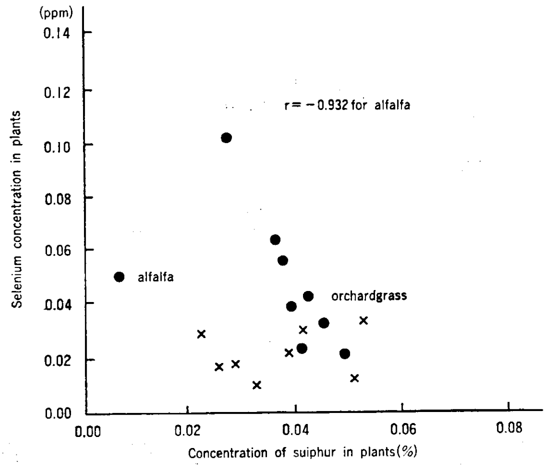

Fig. 5. Relationship between sulfur and selenium concentration in plants.

Second experiment ;

Forage Yield

The forage yield for five yiers per ha is shown in Table 11. Alfalfa yield on barnyard manure with NPK plot was 40,635 kg/ha/5 years (dry matter) and that of smooth bromegrass was 8,963 kg/ha/5 years. The yield of alfalfa and smooth bromegrass shown by alternate row on barnyard manure with the chemical fertilizer plots (BMF-plot) was 35,855 kg/ha/5 years and that of smooth bromegrass was 3,891 kg/ha/5 years. The yield of alfalfa and smooth bromegrass sowed in alternate rows on the non-barnyard manure and chemical fertilizer plots (F-plot) was 38,531 kg/ha/5 years. The ratios of forage yields on the experimental plots were 100 for alfalfa, 22.1 for smooth bromegrass, 98.0 for alternate row plants with barnyard manure, and 95.0 for that without barnyard manure. These forage yield were the average on Hokkaido, except that of smooth bromegrass single plot. But all these plants applied non-nitrogen fertilizer, therefore the nitrogen compounds in plants seemed to be fixed primary by alfalfa root nodule bacteria and nitrogen fix-bacteria.

Concentrations of macro nutrients in the forage

The concentrations of macro nutrients absorbed by the plants are shown in Table 12. The nitrogen concentration in alfalfa was higher than that in smooth bromegrass, and nitrogen in smooth bromegrass sowed in alternate rows was higher than that sowed in single rows. These nitrogen or calcium concentrations in forage were affected by interspecific difference of plants, but not by fertilizer treatments.

Concentrations of micro nutrients in the forage

The micro nutrient concentrations are shown in Table 13. The concentrations of micro nutrients in the forage were not different for copper and zinc,

Table 11. Forage yield of second experiment for 5 years * (kg/ha/5 years)

			1st			2nd			3rd			4th			5th			*Dry mattre Total	ratio
			fresh weight kg/ha	dry matter kg/ha	Dry matter %	fresh weight kg/ha	dry matter kg/ha	Dry matter %	fresh weight kg/ha	dry matter kg/ha	Dry matter %	fresh weight kg/ha	dry matter kg/ha	Dry matter %	fresh weight kg/ha	dry matter kg/ha	Dry matter %		
Alfalfa single BMF-plot		1 cutting	5,650	1,131	19.7	21,250	4,318	20.3	34,250	6,563	19.16	16,160	3,167	16.6	10,500	1,734	16.5	*16,913	
		2 "	11,111	2,179	19.6	21,000	5,040	24.0	22,500	4,548	20.21	14,140	2,077	14.7	9,000	2,592	28.8	16,436	
		3 "	—	—	—	17,250	2,803	16.3	14,750	2,224	15.08	6,560	1,311	20.0	4,555	948	20.8	7,286	
		Total	16,761	3,310		59,500	12,161	20.4	71,500	13,335	18.65	36,860	6,555	17.8	24,055	5,274	21.9	40,635	100
Smooth bromegrass gingle BMF-plot		1 cutting	3,040	645	21.2	7,400	1,906	25.8	12,000	2,179	18.13	3,130	761	22.3	480	92	19.1	5,583	
		2 "	4,560	894	19.6	3,100	620	20.0	2,250	599	26.62	0	0		0	0	—	2,113	
		3 "	—	—	—	3,100	620	20.0	3,500	646	18.46	0	0		0	0		1,266	
		Total	7,600	1,540		13,600	3,146	23.1	17,750	3,424	19.29	3,130	761	22.3	480	92	19.1	8,963	22
Alternate row BMF-plot	Alfalfa	1 cutting	2,609	509	19.5	16,115	3,650	22.7	32,300	6,248	19.53	20,080	3,903	19.4	12,250	2,096	17.1	16,406	
		2 "	6,305	1,229	19.4	15,909	3,500	22.0	15,500	3,149	20.32	15,810	2,243	14.2	8,675	2,403	27.7	12,524	
		3 "	—	—		12,376	2,750	22.2	16,500	2,154	13.06	4,770	1,002	21.0	5,100	1,019	20.0	6,925	
		total	8,914	1,738		44,400	9,900	22.3	64,000	11,551	18.05	40,660	7,148	17.8	26,500	5,518	20.8	35,855	
	smooth brome-grass	1 cutting	1,740	339	19.5	3,885	880	22.0	5,250	725	13.81	0	0		0	0	—	1,944	
		2 "	1,413	274	19.4	2,296	505	21.9	2,515	395	15.70	0	0		0	0	—	1,174	
		3 "	—	—		2,970	660	17.3	1,100	113	10.27	0	0		0	0	—	773	
		total	3,153	613		9,151	2,045	20.6	8,865	1,233	13.91	0	0		0	0		3,891	
		Total	12,067	2,351		53,551	11,945		72,865	12,784		40,660	7,148		26,500	5,518		39,746	98
Alternate row F-plot	Alfalfa	1 cutting	1,522	297	19.5	15,000	3,300	22.0	26,500	5,394	20.36	20,580	4,156	20.2	12,600	2,255	17.7	15,402	
		2 "	4,783	933	19.5	13,500	2,957	21,9	14,000	2,887	20.62	14,060	2,098	14.9	11,400	3,067	26.9	11,942	
		3 "	—	—	—	13,000	2,249	17.3	10,250	1,737	16.95	5,720	1,221	21.0	4,625	966	20.9	6,173	
		total	6,305	1,230		41,500	8,506		50,750	10,018	19.74	40,360	7,475	18.5	28,625	6,288	22.0	33,517	
	smooth brome-grass	1 cutting	1,739	313	18.0	7,100	1,633	23.0	6,650	1,095	16.47	0	0		0	0	—	3,041	
		2 "	1,957	358	18.3	2,900	580	20.0	2,500	410	16.40	0	0		0	0	—	1,348	
		3 "	—	—	—	2,881	498	17.3	1,200	127	10.58	0	0		0	0	—	625	
		total	3,696	671		12,881	2,711		10,350	1,632	15.77	0	0		0	0	—	5,014	
		Total	10,001	1,901		54,381	11,217		61,100	11,650		40,360	7,475			6,288		38,531	95

Table 12. Concentrations of macro nutrients in forage for 5 years

		Tota l nitrogen N	Phosphorus P	Potassium K	Calcium Ca	Magnesium Mg
BMF plot	*alfalfa	3.00±0.56	0.18±0.09	2.32±0.56	0.87±0.18	0.33±0.21
	*smooth	1.52±0.58	0.15±0.07	2.27±0.50	0.31±0.11	0.19±0.10
BMF	**alfalfa	3.05±0.48	0.19±0.10	2.38±0.63	0.28±0.17	0.32±0.17
non BM	**alfalfa	3.03±0.40	0.18±0.09	2.33±0.59	0.84±0.18	0.35±0.12
BMF	**smooth	2.51±0.99	0.14±0.04	2.88±0.71	0.32±0.07	0.37±0.20
non BM	**smooth	2.44±1.02	0.15±0.04	2.76±0.77	0.28±0.08	0.21±0.11

* alfalfa or smooth bromegrass only. ** alternate row.

Table 13. Concentration of micro nutrients in forage for second experiment

(ppm)

			single	Alternate row with BM*	Alternate without BM*
fertilizations	Cu	Alfalfa	8.1± 2.0	8.2± 2.5	8.1± 2.2
		Smooth bromegrass	7.0± 2.6	9.2± 3.4	9.1± 3.3
	Mn	Alfalfa	55.5±15.6	59.3±19.3	54.2±17.1
		Smooth bromegrass	123.3±82.5	116.3±53.9	119.7±51.9
	Zn	Alfalfa	55.0±17.2	48.4±14.9	51.7±20.5
		Smooth bromegrass	46.3±14.3	55.5±15.9	51.0±15.5
			1st	**2nd**	**3rd cutting**
cuttings	Cu	Alfalfa	6.3± 2.8	8.9± 1.1	9.1± 1.0
		Smooth bromegrass	5.1± 2.6	9.9± 1.0	10.8± 1.6
	Mn	Alfalfa	48.0±14.5	52.2± 7.8	69.2±20.1
		Smooth bromegrass	72.8±21.5	136.3±40.5	178.8±75.3
	Zn	Alfalfa	46.9±13.5	49.3±17.8	59.0±19.7
		Smooth bromegrass	44.3±16.7	51.8±13.8	57.3±12.6

			1st	2nd	3rd	4th	5th year
years	Cu	Alfalfa	—	9.3± 0.4	6.8± 3.0	8.3± 2.7	8.2± 0.6
		Smooth bromegrass	—	9.6± 1.7	7.3± 4.0	4.0	7.85
	Mn	Alfalfa	—	73.0±23.6	47.2±10.9	55.7±8.55	49.8±17.6
		Smooth bromegrass	—	166.0±73.6	90.3±30.0	114.0	55.3
	Zn	Alfalfa	—	39.4± 6.1	72.2±13.3	56.7±18.3	38.5± 2.3
		Smooth bromegrass	—	38.7± 7.4	61.1±11.7	76.0	34.8

		Alfalfa	Smooth bromegrass
species	Cu	8.11±2.55	8.23±3.26
	Mn	56.7±17.6	124.5±67.6
	Zn	51.7±18.2	47.0±14.4

* BM ; barnyard manure

but were higher for manganese in smooth bromegrass than in alfalfa with the same fertilization. The variations of chemical property on these soils for 5 years were not great to fertilizations or in the different years, but were great depending on the kind of plant.

From these results, we think that some long-term paddy soil was suitable for immediate use as alfalfa field, but it was important to analyse soils and some fertilization. The contents of the soils after 5 years of growth were shown in Table 14.

Third experiment;

Dry matter yield of alfalfa and smooth bromegrass are shown in Table 15. The dry matter yields of alfalfa and smooth bromegrass of the 1st cutting in

Table 14. Variations of chemical property of soils

		Start	1st	2nd	3rd	4th	5th
pH value (H_2O)		5.81	5.72	5.63	5.44	5.86	6.17
Total nitrogen %		0.22	0.26	0.29	0.30	0.36	0.26
Available	P*	0.92	2.99	3.45	3.54	4.58	12.63
	K**	0.20	0.43	0.20	0.33	0.52	0.85
Exchangeable	Ca**	4.17	5.47	5.33	5.22	6.46	6.89
	Mg**	1.43	2.23	1.18	2.17	2.30	3.69
	Cu	6.0	6.0	6.6	1.7	3.5	2.3
Micronutrients	Mn ppm	66.0	66.0	65.0	79.0	71.0	54.0
	Zn	4.5	4.0	3.9	2.9	4.9	4.5

* mg and ** meq./100 g dry soil

Table 15. Dry matter yield of alfalfa and smooth bromegrass
May 3. Seeding, July 24. Harvest

Plant height (cm)	Alfalfa	Smooth bromegrass
Ammonium chloride	23.8	25.5
Ammonium sulfate	34.4	25.8
Ammonium nitrate	36.4	26.0
Fresh weight (kg/m^2)		
Ammonium chloride	1.08	0.68
Ammonium sulfate	1.22	0.71
Ammonium nitrate	1.32	0.75
Dry matter yield (g/m^2)		
Ammonium chloride	216	52.5
Ammonium sulfate	244	53.0
Ammonium nitrate	264	53.9

the 1st year increased from the 0-plot to the 20-plot, but decreased with increase of nitrogen. The average amounts of alfalfa dry matter were 216, 244, and 264 g/m^2 from the ammonium chloride, ammonium sulfate and ammonium nitrate plots, respectively, while those for smooth bromegrass were 52.5, 53.0, and 53.9 g/m^2.

Total nitrogen, nitrate, and nitrite concentration in both plants[12]

The concentrations of total nitrogen, nitrate, and nitrite in both plant are shown in Table 16 and Fig. 6a and 6b. The concentrations of total nitrogen in alfalfa from 2.45 on the 0-plot to 3.22 per cent on the 40-plot for ammonium chloride. The concentrations of total nitrogen in alfalfa ranged from 3.15 on the 0-plot to 2.99 per cent on the 40-plot for ammonium sulfate, and 3.31 and 3.26 per cent, for ammonium nitrate. The concentrations of total nitrogen in smooth bromegrass ranged from 3.35 on the 0-plot to 3.11 per cent on the 40-plot for ammonium chloride. The concentrations of total nitrogen in smooth bromegrass ranged from 3.48 on the 0-plot to 3.41 per cent on the 40-plot for ammonium sulfate, and 3.04 to 3.24 per cent for ammonium nitrate. The concentrations of nitrate in alfalfa ranged from 0.002 on the 0-plot to 0.134 per cent on the 40-plot for ammonium chloride, and from 0.001 to 0.099 per cent for ammonium sulfate, and from 0.009 to 0.175 per cent for ammonium nitrate. The concentrations of nitrate nitrogen in smooth bromegrass varied from 0.013 on the 0-plot to 0.356 per cent on the 40-plot for ammonium chloride, and from 0.111 to 0.489 per cent

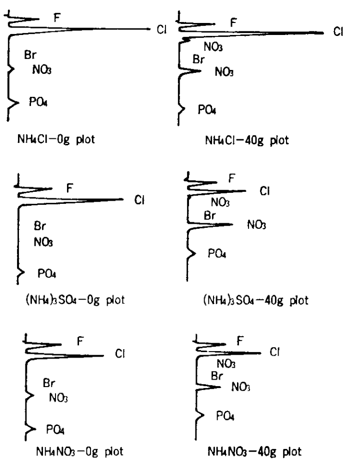

Fig. 6 a. Nitrate and nitrite concentrations in alfalfa 7 weeks after 1st cutting.

At establishment stage, nitrogen of 0, 5, 10, 20 and 40 g/m^2 was added to each plot, and after 1st cutting, amounts of 1/2 of basal fertilizer of nitrogen were added to each plot.

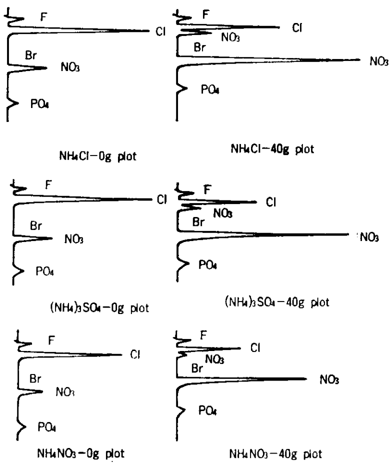

Fig. 6 b. Nitrate and nitrite concentrations in smooth bromegrass 7 weeks after 1sn cutting.

At establishment stage, nitrogen of 0, 5, 10, 20 and 40 g/m^2 was added to each plot, and after 1st cutting, amounts of 1/2 of basal fertilizers of nitrogen were added to each plot.

for ammonium sulfate and from 0.050 to 0.653 per cent for ammonium nitrate.

The concentrations of nitrite in alfalfa ranged from 0 on the 0-plot to 22 ppm on the 40-plot for ammonium chloride, from 0 to 21 ppm for ammonium sulfate, and from 0 to 12 ppm for ammonium nitrate.

The concentrations of nitrite in smooth bromegrass ranged from 0 on the 0-plot to 47 ppm on the 40-plot for ammonium chloride, from 0 to 38 ppm for ammonium sulfate, and from 0 to 37 ppm for ammonium nitrate.

The interspecific difference of total-N, nitrate-N, and nitrite-N absorption in alfalfa and smooth bromegrass in shown in Table 16. As can be seen in the table, the average concentration of total-N for alfalfa plants was 3.04±0.36 per cent, while the average for smooth bromegrass was 3.37±1.72 per cent. The total-N concentration in smooth bromegrass was higher than that in alfalfa. The concentration of nitrate-N in the alfalfa plants was 0.05±0.053 per cent and that in the smooth bromegrass plants was 0.28±0.179 per cent. The concentration of nitrate in the smooth bromegrass was higher than that in alfalfa. The concentration of nitrate was also higher in smooth bromegrass. Therfore, the quality alfalfa was considered more favorable than smooth bromegrass as forage for cattle.

Table 16. Interspecific difference of total-N, NO_3-N and NO_2-N absorption in both plants

	alfalfa			smooth bromegrass		
	T-N**	NO_3-N**	NO_3-N*	T-N**	NO_3-N**	NO_2-N*
NH_4Cl	2.93	0.042	22	3.41±1.74	0.245	47
$(NH_4)_2SO_4$	2.91	0.050	21	3.36±1.12	0.324	38
NH_4NO_3	3.30	0.070	12	3.35±2.10	0.301	37
Average	3.04±0.36	0.054±0.053	—	3.37±1.72	0.281±0.179	—

* 40-plot only ppm. ** %

Summary and Conclusion

The relationships between the nutrients absorbed from the soils and the growth habit of alfalfa and orchardgrass or smooth bromegrass with some fertilizations on different soils were checked in a cold area of Hokkaido, Japan.

The experiments were divided into three parts. In the first experiment, the soils used were Nopporo diluvial, Uenae pumice volcanic, Shinotsu alluvial, and Bibai peat soil. In second experiment, Eniwa volcanic soil was used, and in the third experiment, Nopporo diluvial soil was used.

Results from the first experimental studies indicate that the ratio of forage yield from barnyard manure with complete fertilizer plot, complete fertilizer with sulphur, and complete fertilizer with chlorine was 100 : 94 : 92 for alfalfa, and 100 : 92 : 94 for orchardgrass, respectively. The nitrogen concentraion of alfalfa also ranged from 3.43 to 3.08 per cent depending on the kind of soil, the fertilization, the cutting time and the growth years. On the other hand, that of orchardgrass was from 2.76 to 1.76 per cent lower than that of alfalfa. Nitrogen concentration of alfalfa forage, everywhere and at any time, was higher than that of orchardgrass. The quality of nitrogen in alfalfa forage is higher than that in orchardgrass or smooth bromegrass because of the low concentration of nitrate and nitrite and the high concentration of calcium, iron and selenium in alfalfa forage. This is due to the interspecific difference of the absorption ability of nitrate, nitrite, iron, and selenium.

Results from the second experimental studies for the process from paddy soil to forage field indicate that the ratio of single alfalfa yield sowed on branyard manure with chemical fertilizer plot to that of smooth bromegrass is 100 : 22. The ratio of yield of alfalfa and smooth bromegrass sowed in alternate rows on barnyard manure and chemical fertilizer plots (BM-plot) to alfalfa and smooth bromegrass sowed in alternate rows on non-barnyard manure and chemical fertilizer plots (F-plots) was 98 : 95.

In the second experiment, nitrogen fertilizer is not used for all plots.

Results from the third experimental studies regarding the difference of applied nitrogen compound, the concentrations of nitrate in the alfalfa plants ranged from 0.001 on the 0-plot to 0.175 per cent on the 40 g/m^2 plot and in smooth bromegrass ranged from 0.013 on the 0-plot to 0.635 per cent on the 40 g/m^2 plot.

Results from 1, 2, and 3 experimental studies indicate that, 1) Alfalfa may grow even on peat and volcanic soil with some fertilization, in cold areas Hokkaido, Japan. 2) The maintenance of alfalfa sowed is also possible with non-nitrogen fertilizer. In this case, the yield was 74–97 per cent for alfalfa plot with sufficient nitrogen fertilizer applied. It is the same in paddy soil. 3) The

Table 17. Amounts of fertilizer for maintenance of alfalfa plants

* kg ha^{-1} year^{-1}

Kind of fertilizer	N	P	K	Ca	Mg	S
	Amounts as element*					
Fused magnesium phosphate 300 kg ha^{-1} year^{-1}	—	26.4	—	43	27	—
Potassium sulfate 300 kg ha^{-1} year^{-1}	—	—	135	—	—	36
Calcium carbonate 167.5 kg ha^{-1} year^{-1}	—	—	—	67	—	—
Total	—	26.4	135	110	27	36
Amounts absorbed by alfalfa kg ha^{-1} year^{-1}**	290	28	261	110	18	38

** The yield (dry matter) of alfalfa plant was 9,063 kg ha^{-1} year^{-1}. Dairy manure must apply every 5 or 7 years, when the alfalfa renovation.

concentration of nitrogen in smooth bromegrass sowed in alternate rows with alfalfa is able to increase 1.0 per cent over that of single smooth bromegrass plant. 4) The concentrations of iron and selenium in alfalfa herbage were higher than those orchardgrass or smooth bromegrass, regardless of the kind of soil or the cutting time. 5) The concentrations of nitrate and nitrite in alfalfa herbage were lower than those of orchardgrass or smooth bromegrass.

In conclusion, from these results, we think that many unfertile soils (including paddy soil) can be used immediatly of alfalfa fields with chemical fertilization and without barnyard manure, and alfalfa and smooth bromegrass are the best feed for dairy cattle. The fertilization of alfalfa field for maintenance is shown in Table 17 and 18 for example, on Nopporo diluvial soil, fused magnesium, potassium sulfate, and calcium carbonate of 300, 300, and 168 kg ha^{-1}, $year^{-1}$ respectively were needed. And 2370, 627, and 136 ha^{-1}, $year^{-1}$ of granular borax, zinc sulfate and copper sulfate were needed, respectively.

Table 18. Amounts of micro fertilizer for maintenance of alfalfa plants

* g $ha^{-1}year^{-1}$

Kind of microfertilizer	Fe	B	Mo	Mn	Zn	Cu	Cl
Granul borax 2370g*	—	272	—	—	—	—	—
Zinc sulfate 627 g ($ZnSO_4$)	—	—	—	—	254	—	—
Copper sulfate 136 g ($CuSO_4$)	—	—	—	—	—	54	—
Amounts absorbed by alfalfa (g ha^{-1} $year^{-1}$)	1389	272	1.8	335	254	54	—

Boron content is 12% in borax, zinc content is 41% in zinc sulfate, and copper content is 40% in copper sulfate.

** The yield (dry matter) of alfalfa plant was 9,063 kg ha^{-1} $year^{-1}$.

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要　約

異なる4種の土壌に施肥法を変えて，アルファルファ (*Medicago sativa* L.)，オーチャードグラス (*Dactylis glomerata* L.) あるいはスムースブロムグラス (Bromus inermis Leyss) が栽培され，その生長体とその土壌から吸収された栄養素の相互関係が，北海道の寒冷地帯において研究調査された。

この実験は，その目的から，三つの部分に分けられた。第1の実験に使用された土壌は，野幌洪積土壌，植苗粗粒火山性土壌，篠津沖積土壌，そして美唄高位泥炭土壌であった。第2の実験には恵庭火山性土壌であり，第3の実験には，野幌重粘土壌が使用された。

第1の実験はつぎのような結果であった。すなわち，堆厩肥と完全な化学肥料区，硫酸系の完全な化学肥料区，および塩素系の完全な化学肥料区のアルファァルファの牧草の収量比は100:94:92であり，オーチャードグラスでは100:92:94であった。また，アルファルファの窒素含有率は，土壌の種類，施肥法の相違，刈取時期および生育年次で3.43から3.08%であり，オーチャードグラスでは2.76から1.76%で，アルファルファの含有率より，年次および土壌の種類に関係なく常に低かった。アルファルファ牧草の中の窒素の品質はオーチャードグラス，あるいはスムースブロムグラスより，より良質のものであった。それは，硝酸や亜硝酸が少なく，カルシウム，鉄およびセレニウムの含有率が，アルファルファにおいて高いためである。その理由は植物の例えば硝酸，鉄およびセレニウムの吸収の種間差にあった。

水田土壌を飼料畑化する第2の実験結果ではつぎのようなことが明らかとなった。すなわち，堆厩肥と化学肥料で栽培されたアルファルファとスムースブロムグラスの単播区の収量比は100:22であった。堆厩肥と化学肥料でアルファルファとスムースブロムグラスを交互に播種した区 (BM-plot) と無堆厩肥の化学肥料で交互に播種された区 (F-plot) との収量比は98:95であった。実験2のすべての化学肥料には窒素肥料を使用していない。

施用された窒素化合物の相違による，第3の実験結果から，アルファルファ植物中の硝酸態の窒素含有率は0.001から0.175%の低い範囲にあり，スムースブロムクラスでは0.013から30.635%と高い範囲にあり，このときの施用窒素量は0から40 g/m^{2}であった。

これらの実験1, 2, および3の果結から，つぎのことが指唆された。1) アルファルファは寒冷地の北海道の高位泥炭土壌や粗粒火山性土壌においてさえ，施肥によって栽培が可能であること。2) またアルファルファは十分な窒素肥料を施用して栽培された場合の74～97%の収量が，無窒素施肥でも得られた。3) アルファルファと交互条播されたスムースブロムグラスの窒素含有率は，窒素無施用のスムースブロムグラス単播の窒素含有率より1.0%高い値を示した。4) アルファルファ牧草の鉄やセレニウムの含有率はオーチャードグラスやスムースブロムグラスの含有率より，いつでもどこでも，高い値を示した。5) アルファルファ地上部中の硝酸や亜硝酸の含有率はオーチャードグラスやスムースブロムグラスのそれより低い含有率であった。

これらの研究調査の結論として，われわれはつぎのような考えをもつに至った。すなわち，すべての低肥沃度土壌は直ちにアルファルファ圃場として（水田土壌を含む）利用可能である。それには堆厩肥は用いなくても，化学肥料を施用することによって可能である。そしてこれらのアルファルファやスムースブロムグラスは乳牛のために最高の飼料である。アルファルファ圃場の維持管理のための施肥法が，北海道，野幌洪積土壌の例で，表17，18に表示した。すなわち，熔成燐肥，硫酸カリ，そして炭酸カルシウムがそれぞれ300, 300, 168 kg ha^{-1}, $year^{-1}$が施用されることよがよい。そして粒状硼砂が2370 g，硫酸亜鉛627 g，さらに硫酸銅が136 g ha^{-1}, $year^{-1}$が施用されるとよい。

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