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Response of Magnesium Content of Forages to Potassium Application in Grassland

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칼륨 施用에 따른 牧草中 마그네슘含量의 季節變化

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摘　　要

봄철에 자라는 牧草를 다른 季節의 목초와 比較하면 어떤 特性이 있는지, 또 그 時期의 칼륨질 肥料의 施用이 牧草의 水分 또는 마그네슘 含量에 어떤 影響이 있는가를 알아보고자 오차드그라스(*Dactylis glomerata* L.) 採草地에서 시험했는데, 그 結果는 칼륨 施用에 따른 無機質과 水分含量에 季節差異가 뚜렷하다는 것이었다. 本 試驗에서 봄철(4月)에 生育하는 牧草의 無機質含量은 다른 季節보다 큰 변화를 나타냈으며, 칼륨含量은 높고 마그네슘含量은 가장 낮았다. 또한 봄철 牧草의 水分含量은 높았으며, 칼륨 施用에 의해 敏感한 變化를 보였다.

Ⅰ. INTRODUCTION

In most circumstances farm animals derive a high proportion of their mineral nutrients from the feeds and forages that they consume. For this reason the factors that determine the mineral contents of the vegetative parts of plants and their seeds are the factors that basically determine the mineral intakes of livestock (Foth, 1978; Underwood, 1981; McDonald *et al.*, 1985). The content of all minerals in crop and forage plants depends on four basic interdependent factors: (1) the genus, species or strain (variety), (2) the type of soil on which the plant grows, (3) the climatic or seasonal conditions during growth, and (4) the stage of maturity of the plants. When mineral nutrient in herbage are marginal for animal requirements, changes in contents of forage brought about by climatic or seasonal influences and by plant maturity can obviously be significant factors in the incidence or severity of deficiency states in livestock wholly or largely dependent on those plants (Underwood, 1981).

When the amount of potassium application is to be excessive for the forage plants, harmful effects to plant growth can appear (Follett and Wilkinson, 1985). At the same time, potassium application has adverse influences to other mineral contents of forage plants such as magnesium or calcium (Kemp, 1960; Yamasaki, 1981; Hatanaka *et al.*, 1985). And this relation between potassium and magnesium in diet may result in a disorder in ruminant livestock (McDonald *et al.*, 1985; Reid and James, 1985).

In adult ruminants a condition known as hypomagnesaemic tetany associated with low blood serum levels of magnesium (hypomagnesaemia) has been recognized since the early of 1930s. The exact cause of hypomagnesaemic tetany in ruminant animals is unknown. However, some researchers believe that high dietary intake of potassium seemed to interfere with the absorption and metabolism of magnesium in the animal, which may be one of the contributory factors in the incidence of hypomagnesaemia or hypomagnesaemic tetany (Kemp, 1958; Metson *et al.*, 1966; Newton *et al.*, 1972; Kawagoe

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and Kayama, 1981; Greene *et al.*, 1983).

While surveying the literature, the following questions arose. (1) What are the characteristics of spring grass, which differ from those on other seasons? (2) What are the effects of potassium application on potassium, magnesium and water contents of forages? (3) Is there any effect of water intake on magnesium availability in ruminants? In order to solve these questions, a research was done mainly on potassium behavior in grassland ecosystem (Kim, 1988). In the present report, the response of magnesium content of forage plants to potassium was investigated mainly on orchardgrass (*Dactylis glomerata* L.) meadow.

Ⅱ. MATERIALS AND METHODS

The investigation was carried out at Nagoya University Farm.

Plant samples were taken during 22~25 April, 1985, from the meadows and the grazing pastures. About 500 g fresh weight (FW) each of forages were collected from 4 to 10 different sites of the grasslands. Forage species investigated were Italian ryegrass (*Lolium multiflorum* Lam.), orchardgrass (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* Schreb.), alfalfa (*Medicago sativa* L.), red clover (*Trifolium pratense* L.) and wild common vetch (*Vicia sepium* L.).

During a period from June 3, 1985 to July 29, 1987, forages were sampled from an orchardgrass meadow, which had been established in 1984. On June 3 in 1985, the meadow was trimmed at 5 cm above soil surface and applied urea at a rate of 100 kg N per ha. Forage samples in the meadow were taken 8 times from July 18, 1985 to July 29, 1987.

On July 18, 1985 when plant heights were from 30 to 60 cm, 15 smaller quadrats (25 cm×25 cm) were set on the meadow to obtain the forage and soil samples. According to the result of the soil survey on July 18, five plots of 20 m^2 with similar level of exchangeable soil K content were selected and treated with 5 different levels of K fertilizer. The treatments were as follows; 0 (zero), 100 (low), 300 (medium), 300 kg+16 ton of farm yard manure (medium+FYM) and 1,000 kg(high) K_2O/ha. Urea (325 kg/ha), fused phosphate (300 kg/ha) and superphosphate (300 kg/ha) were simultaneously applied to each plot on July 22, 1985 as to supply 150 kg N and 120 kg P_2O_5/ha. After every harvesting date except in June, 1986, same rates of K of (0:1:3:3:10) for the treatment and adequate amounts of N and P fertilizers were applied. Therefore, the top dressed K fertilizer level after each harvest was the same between K-medium and K-(medium+FYM) plots.

In October and in December, 1985, three larger quadrats (1m×1m) were set to each plot to take forage samples. During a period from April, 1986 to July, 1987, all the forages grown in each plot were cut. Representative forage samples were taken from 2 or 5 different parts of each plot to determine the water, K and Mg contents of them.

Samples were immediately air-dried at 80~85 ℃ and milled for K and Mg analyses. Then, a half gram each of the milled sample was extracted for 18 h by 25 ml of 1M hydrochloric acid, and adequate volume of extracts was diluted with distilled water up to 100 ml and filtered. The diluted solutions were directly subjected to K and Mg determination by flame photometry (FLA, Eko Seikisangyo Co. Ltd., Tokyo) and by atomic absorption/flame emission spectrophotometry (AA-646, Shimadzu Co. Ltd., Kyoto), respectively.

Ⅲ. RESULTS AND DISCUSSION

Table 1 shows Mg contents of plants grown in meadows and grazing pastures in the spring period. Leguminous plants grown in the grasslands contained higher Mg content than gramineous plants. Gramineous forages had 1.3~2.6 mg and 1.2~2.4 mg/g on a dry matter basis in meadow and in pasture, respectively. The leguminous forage except for alfalfa showed 2.0~5.1 mg and 1.6~4.8 mg/g DW in meadow and in pasture, respectively. Alfalfa had mean contents of 1.9 mg in meadows, while NRC (1981) listed that the Mg content of the forage ranged 2.3~3.3 mg/g DW. The forage species had comparatively lower Mg content than the same species reported elsewhere (Harada, 1967; Harada and Shinohara, 1970). Present study was carried out in April when plants grow most luxuriantly, and it may be the reason why the above results obtained (Loneragan, 1973). Consequently, it is necessary to investigate seasonal changes of Mg contents of forages.

Table 1. Magnesium contents of plants grown in meadow and in pasture[1)]

(mg Mg/g DW)

Species	No. of samples	Meadow		Pasture	
		Minimum-Maximum	Average[2)]	Minimum-Maximum	Average[2)]
Italian ryegrass	10	1.3−2.5	1.6±0.4	1.2−2.0	1.6±0.3
Orchardgrass	10	1.6−2.6	2.0±0.4	1.2−2.3	1.8±0.3
Tall fescue[3)]	10	1.3−1.8	1.5±0.2	1.4−2.4	1.9±0.3
Alfalfa	10	1.3−2.5	1.9±0.4	−	−
Red clover	10	2.5−5.1	3.6±0.9	2.7−4.8	3.8±0.7
White clover	10	2.9−4.1	3.3±0.4	2.4−3.9	3.1±0.5
Wild common vetch	10	2.0−3.7	2.4±0.5	1.6−3.0	2.4±0.4

1) All the samples were taken on April 22-24, 1985.

2) Mean±S.D.

3) Four samples were taken in meadow.

The effects of fertilized K level and harvested season on water content, K and Mg contents of forage plants were determined from October, 1985 to July, 1987, and relationships between the items were estimated. The results are shown in Table 2. Forage K content raised with the increase of K fertilizer level during the period as previously described (Kim *et al.*, 1988b). The Mg content decreased and water content of forage plants increased somewhat with the increase of fertilized K level. As the result, Mg and water contents have close negative and positive relationships, respectively, with K content of the forage plants at statistically significant level ($P<0.05$) except for the relation with Mg content of October, 1985. Though the results were not presented in tables, there was no significant relationship between Mg and water contents of forage plants in the present experiment except a negative relationship formed in July, 1987. Water content of the forage plant was the lowest in June, 1987, and the highest in April, 1986. The low water content of June 1987 may have been derived from an inclusion of standing dead with long period of non utilization of the meadow, because it was not so low in the same month of 1986. On the other hand, forage Mg content was lower than that of other periods in most of fertilization levels of K in April, 1986 when the forage grew most vigorously and in June, 1987 when forages were taken 10 months after the foregoing harvest. The highest Mg content of forage was observed in December, 19 85 when the forage fresh yield was the lowest and in July, 1987 when the yield was the secondary low (Kim *et al.*, 1988b).

Water content in the forage plants was also the highest in the spring season. Not only the well known antagonistic relation between the contents of K and Mg in plants (Hashimoto, 1953; Yamasaki, 1981), but also synergistic relation between K content and water content of the forage plants was found in the present study. From the facts, it was considered that in mineral metabolism of grazing animals is affected by moisture and K contents of forages. And the goats showed deep relations of water intake with Mg utilization and K metabolism (Kim *et al.*, 1988a). More intakes of water and K had opposite reaction with Mg utilization in the ruminants. Namely, more intake of water seemed to advance Mg utilization, while that of K did interfere the utilization.

Table 2. Effects of potassium level and harvesting season on water content, plant potassium and magnesium contents and relationship between the items[1)]

Period	Item	K-level[2)]					Relationship[3)]	
		Zero	Low	Medium	Medium+	FYMHigh	WC[4)]:K	Plant K:Mg
Oct. 8,	WC[4)]	76 ±2	73 ±1	77 ±2	76 ±1	79 ±2	r=0.7272	r=−0.2632
1985	Plant K	34 ±5	30 ±4	36 ±1	40 ±3	41 ±2	(P<0.01)	NS[5)]
	Plant Mg	2.4±0.2	2.6±0.2	2.3±0.2	2.4±0.2	2.2±0.1	n=15−2=13	n=15−2=13
Dec. 4	WC	76 ±8	75 ±0	77 ±1	79 ±1	76 ±1	r=0.5052	r=−0.8273
	Plant K	28 ±2	32 ±0	37 ±1	37 ±0	36 ±1	(P<0.10)	(P<0.001)
	Plant Mg	3.6±0.2	2.9±0.1	2.6±0.2	2.6±0.1	2.2±0.1	n=15−2=13	n=15−2=13
Apr. 24,	WC	84 ±1	86 ±0	88 ±1	89 ±0	87 ±1	r=0.8783	r=−0.4311
1986	Plant K	36 ±6	43 ±3	54 ±3	57 ±3	59 ±2	(P<0.05)	(P<0.05)
	Plant Mg	2.4±0.4	2.2±0.4	2.0±0.3	2.0±0.2	1.7±0.3	n=5−2=3	n=25−2=23
June 2	WC	77 ±3	81 ±0[6)]	82 ±1	80 ±1	81 ±1	r=0.7833	r=−0.4356
	Plant K	33 ±5	49 ±4	57 ±1	56 ±6	60 ±4	(P<0.001)	(P<0.05)
	Plant Mg	2.9±0.2	2.8±0.4	2.7±0.4	2.6±0.2	1.9±0.3	n=23−2=21	n=23−2=21
July 24	WC	74 ±2	74 ±3	76 ±3	74 ±4	76 ±2	r=0.4763	r=−0.7017
	Plant K	27 ±4	33 ±2	40 ±4	36 ±4	42 ±3	(P<0.05)	(P<0.001)
	Plant Mg	2.9±0.4	2.6±0.3	2.3±0.1	2.3±0.2	1.9±0.1	n=25−2=23	n=25−2=23
June 8,	WC	58 ±1	61 ±1	66 ±1	64 ±1	62 ±1	r=0.6634	r=−0.5994
1987	Plant K	19 ±1	21 ±1	26 ±1	23 ±0	26 ±2	(P<0.01)	(P<0.02)
	Plant Mg	2.5±0.3	1.9±0.3	1.9±0.2	1.9±0.1	1.6±0.2	n=15−2=13	n=15−2=13
July 29	WC	68 ±3	72 ±2	72 ±1	73 ±2	74 ±2	r=0.8573	r=−0.9398
	Plant K	22 ±6	32 ±3	43 ±3	44 ±3	49 ±2	(P<0.001)	(P<0.001)
	Plant Mg	3.9±0.2	2.9±0.1	2.7±0.1	2.6±0.1	2.1±0.2	n=15−2=13	n=15−2=13

1) Mean±S.D. of 3 or 5 replicates.

2) Zero:Low:Medium:Medium+FYM:High = 0:1:3:3:10 except for the 1st ferilization on July 20, 1985, when 1.6 kg/m^2 farm yard manure(FYM) was applicated on MM+FYM.

3) r; correlation coefficient, P; statistically significant level. n; degree of freedom.

4) WC, K, Mg; water content(%), K and Mg content(mg/g DW).

5) NS; statistically not significant.

6) Three samples from five ones were used for calculation.

Table 3 shows the effects of growing season and K application level on the forage K contents on a dry matter and tissue water bases. There were seasonal changes of forage K concentration in a tissue water, and the highest (9.4~14.0 mg/ml) in the summer season and the lowest (6.8~8.8 mg/ml) in the spring. However, within the same harvesting period, there was no large difference among K application levels. It was similar to the result of Jungk (1970). This result was supported by the fact that there was close relationship between K content and water content of forages.

Table 3. Effects of growing season and potassium fertilizer application on forage potassium concentrations on a dry matter and tissue water bases[1,2]

Period	K concentration	Fertilizer K level				
		Zero	Low	Medium	M+FYM	High
October,	Dry matter basis(mg/g DW)[3]	34	30	36	40	41
1985	Tissue water basis(mg/ml)	10.7	11.0	10.7	12.6	10.8
December	Dry matter basis(mg/g DW)	28	32	37	37	36
	Tissue water basis (mg/ml)	8.8	10.6	11.0	9.8	11.3
April,	Dry matter basis (mg/g DW)	36	43	54	57	59
1986	Tissue water basis (mg/ml)	6.8	7.0	7.3	7.0	8.8
June	Dry matter basis (mg/g DW)	33	47	57	56	60
	Tissue water basis (mg/ml)	9.8	12.4	12.5	14.0	14.0
July	Dry matter basis (mg/g DW)	27	33	40	36	42
	Tissue water basis (mg/ml)	9.4	11.5	12.6	12.6	13.2

1) Mean of 3 or 5 replicates.
2) (100-water content) × forage K content on DM basis/water content (mg/ml).

The improvement of Mg utilization by increasing water intake was already shown by Suttle and Field (1966, 1967). Though the results were opposite to their initial hypothesis that a higher water content in spring grass would make worse Mg utilization in ruminants. And here it is required to consider the difference between tap or well water and "plant" water. Orchardgrass plants harvested in spring contained more than 6,000 ppm K on a tissue water basis (Table 3), and the water content of it was more than 84% (Table 2). Sugiyama *et al.* (1985) reported a similar K concentration that spinach plants (*Spinacia oleracea* L.) contained in the ranges from 3,600 to 9,900 ppm on a tissue water basis, and Jungk (1970) insisted that mustard plants (*Sinapis alba*) contained comparatively stable K concentration in the range of 3,600 of 5,600 ppm on a fresh matter basis. While K concentrations of tap water and rain drops of the University Farm were 4.2 ppm and 0.08~0.32 ppm, respectively. Therefore, the ruminants fed fresh grass or grazed on spring grass of higher water content have to consume more water containing more K to meet their dry matter requirements than those fed hay or concentrates and drunk tap or well water *ad libitum*. That may be why the increased water intake made a favourable effect on the Mg utilization in the goat experiment (Kim *et al.,* 1988a).

Ⅳ. SUMMARY

Forages were sampled from an orchardgrass (*Dactylis glomerata* L.) meadow during two years in order to know both the characteristics of spring grass, which differ from those on other seasons, and the effects of potassium application on potassium, magnesium and water contents of forages.

Their is a seasonal difference in the response of mineral and water contents to potassium. Mineral contents in forage possibly show their extremes in the early spring such as April on the present experiment. Namely, the K content of the forage was the highest, while the Mg content was the lowest in April. Other facts worthy to be described were the highest water content and the sensitive response of it to the K fertilization in spring time.

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