韓草誌(J. Korean Grassl. Sci.) 9(3) : 168～173, 1989

Potassium Leaching from Grassland Soil

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草地土壤에서의 칼리 溶脫

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摘 要

草地生態系에 있어서 칼리(K)動態에 關한 硏究의 한 部分으로서, 草地土壤으로 부터의 칼리成分의 溶脫을 알아보기 위해 두가지 實驗을 遂行했는데, 하나는 오차드그라스 採草地의 土壤層別 置換性칼리의 垂直分布를 조사했으며 다른 한가지는 라이시메터를 이용하여 草地土壤으로 부터의 칼리溶脫을 1年間 調査했다.

오차드그라스 採草地안에서 土層間의 置換性칼리 含量의 差는 칼리 無施用區에서는 아주 작았으나 칼리多施用區에서는 그 차이가 顯著했다(實驗 1).

라이시메터를 통해 1년간 나온 溶脫水의 量은 月別 降雨量에 의해 큰 影響을 받았는데 그 양은 1m² 當 471 리터였으며 그에 의한 칼리 溶脫量은 22.3g이었다. 總量의 약 40%의 칼리가 實驗이 시작된 후 첫 두달인 5月과 6月에 용탈되었으며 그 후 목초의 수확을 했던 7月부터 다음해 4月까지의 10個月 동안에 60%인 13.2g의 칼리가 溶脫되었다(實驗 2).

以上의 結果로부터, 土壤表面이 단단하지 못하거나 牧草生育이 좋지 않은 條件에서는 草地土壤에서도 칼리溶脫이 相當量 일어날 수 있음을 알았다. 따라서 造成初期에, 특히 降雨量이 많은 時期에는 草地土壤으로부터 많은 양의 칼리溶脫이 일어날 수 있음을 나타내 주었으나, 永久草地에서는 이와 반대로 土壤中의 칼리溶脫이 많지않다는 것을 示唆해 주었다.

I. INTRODUCTION

As the main pathways of potassium loss from soils, there are crop removal, leaching and run-off (erosion) (Black, 1968). The losses of potassium by leaching in both absolute amount and in percent to fertilized level were below the corresponding figures for nitrogen, calcium and magnesium and above those for phosphorus (Bonner and Galston, 1952; Black, 1968), though they depend on soil textures and rainfall etc. (Mengel and Kirkby, 1978). Potassium can be bound very tightly to clay minerals such as illite or vermiculite. For soils rich in these minerals, potassium leaching rates are relatively low (Mengel and Kirkby, 1978). Clay minerals of the kaolinitic type do not absorb potassium ion(K^+) selectively. High rates of leaching of potassium have therefore been observed in kaolinitic soils.

From the chemical standpoint, soil potassium is often divided into three categories: non-exchangeable, exchangeable and water-soluble. In most soils, the great parts of the potassium, an average of 97-99 % of the total potassium, is non-exchangeable. The remaining 1-3 % are present as the exchangeable and the water-soluble forms (Okajima, 1976; Mengel and Kirkby, 1978). Leaching is considered to influence

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on the vertical distribution of exchangeable potassium in the grassland. The fertilizer element added by top dressing is liable to move down into the soil according to water penetration. Therefore, soil potassium moves down more rapidly in the humid region than in the dry regions (Smith, 1975). The exchangeable or water soluble K is not strongly adsorbed to clay minerals in the soil, and leaching in humid regions removes the available potassium and creates a need for potassium fertilizer when moderate or high crop yields are desired (Foth, 1978). Consequently, potassium leaching is one of important factors concerning the behavior of potassium in grassland and potassium fertility of the grassland.

In this experiment, 1) vertical distribution of exchangeable potassium of soil in the orchardgrass meadow was investigated and 2) potassium leaching was monitored under lysimeter condition throughout one year.

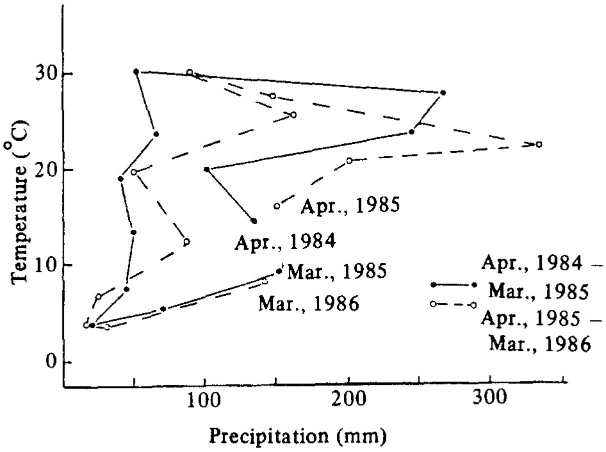

Fig. 1. Temperature and precipitation from April, 1984 to March, 1986 in Nagoya University Farm.

II. MATERIALS AND METHODS

1. An outline of the experimental field

During a period from June 3, 1985 to April 29, 1986, forages and soil were sampled from an orchardgrass meadow in Nagoya University Farm, which had been established in 1984. Figure 1 shows the temperature and precipitation from April, 1984 to March, 1986 in the field. This soil is known to originate from diluvian formations and to contain kaolinite as the dominant clay, and grouped as mineral soil with red yellow color. On June 3 in 1985, the meadow was trimmed at 5 cm above soil surface and applied urea at a rate of 100 kg nitrogen(N) per ha. According to the result of the soil survey on July 18, five plots of 20 m^2 with similar level of exchangeable soil potassium(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 1000 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, same rates of K or (0:1:3:3:10) for the treatment and adequate amounts of N and phosphorus(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.

1-1. On cultivated layer of meadow soil (*Experiment 1*)

On the different five plots, zero, 130, 390, 670 and 1300 kg K/ha were applied until the sampling date (on July and October, 1985). The soil was sampled on December 3, 1985 from the orchardgrass meadow at 3 soil strata; 0-5 cm, 5-10 cm and 10-15 cm.

After air-drying, the soil samples were passed through 2 mm sieve. Ten grams each of dried soil were extracted with 1 M ammonium acetate (pH 7.0) for 18 h and the extracts were filtered through filter paper (Toyo No. 6). After dilution to an adequate level, the filtrates were used for the determination of exchangeable soil K with a flame photometer (FLA, Eko Seikisangyo Co., Ltd., Tokyo).

Soil hardness of the meadow was measured with a soil-inserting hardness calculator (DIK-5520, Daiki Rikakogyo Co., Ltd., Tokyo).

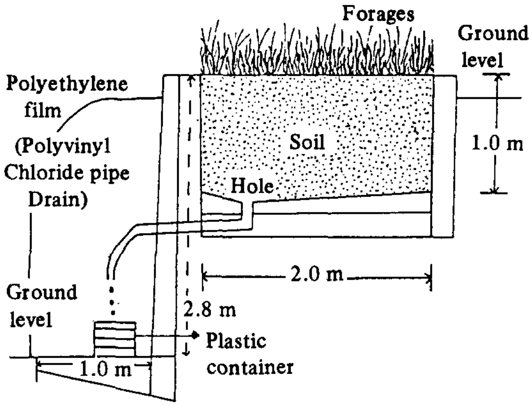

Fig. 2. Sectional plan of the lysimeter.

1-2. Under lysimeter condition (*Experiment 2*)

Figure 2 shows the sectional plan of the lysimeter, which was made of a plastic basin (width; 100 cm X 200 cm, depth; 100 cm) and prepared for the leaching experiment. In the lysimeter situated near the orchardgrass meadow in *experiment 1*, mineral soil had already been filled from about 1 year ago. Before the investigation the upper half of soil was digged out, and then grassland soil was filled into the lysimeter on April 15, 1985. Under the lysimeter, smaller basin (width; 45 X 35 cm, depth; 25 cm) covered with polyethylene film for protecting from rainfall or wind was set for collecting the dropping water from the lysimeter.

Fertilization and sowing were made on April 20, 1985. Eighty seven grams of urea and 200 g of superphosphate and 67 g of potassium chloride were applied to the upper layer of soil in the lysimeter. And then, 6 g of orchardgrass (cv. Aonami) and 2 g of white clover (cv. common) were sown.

Collection of water leached from the lysimeter was done from May, 1985 to April, 1986. After measuring the volume and filtering, the leached water was diluted to adequate volume and analysed K concentration using a flame photometer. Harvesting and topdressing were made from July 17 with the same method described previously. After each harvesting, K fertilizer was applied at K-medium level. Exchangeable soil K content was analysed by the same method in *experiment 1*. Methods for plant K analysis were described previously (Kim et al., 1989). And the K uptake was estimated by multiplying forage K content by dry weight of the forage.

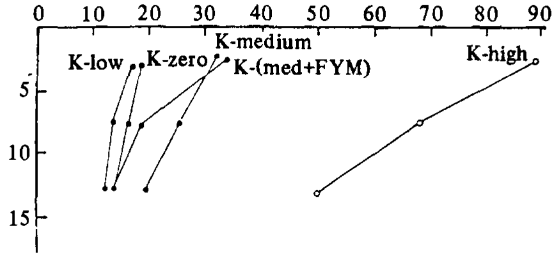

Fig. 3. Distribution of exchangeable soil potassium on orchardgrass meadow (sampled on Dec. 3, 1985).

III. RESULTS AND DISCCUSSION

1. Vertical distribution of exchangeable soil potassium in orchardgrass meadow (*Experiment 1*)

Figure 3 shows the effect of top dressing of different levels of K on the vertical distribution of exchangeable soil K. The exchangeable soil K contents of 0-5 cm and 5-10 cm were affected significantly by the fertilizer K levels. However, the exchangeable soil K decreased with advance of depth at every K fertilizer level, and at 10-15 cm the K content of each plot other than K-high was in a similar range of 12-18 mg/100g soil. The difference in the exchangeable soil K content between the soil layers was very small in K-zero plot, but it was significant in K-high plot. This fact showed that the higher the application level of K, the more K leached into the soil. The results obtained in lower fertilization levels than 670 kg K/ha were similar to the investigation of Doll et al. (1959), who applied 0 to 460 kg K/ha/yr. They recognized that most of fertilized K was held in the top of 7.6 cm and no movement was detected below 15 cm.

The hardness of the soil was above 25 kg/cm^2 at the soil surface.

2. Potassium leaching from soil in grassland (*Experiment 2*)

Table 1. Potassium leaching from the lysimeter

Sampling date		Water volume (liter/m^2)	K-conc. (ppm)	Leached K (g K/m^2)	Leached K[2] (%)
May,	1985	143	34	4.9	22.0
Jun.		103	41	4.2	19.0
Jul.	1)	58	58	3.5	15.7
Aug.		27	62	1.6	7.3
Sep.		56	58	3.3	14.7
Oct.	1)	5	60	0.3	1.3
Nov.		26	55	1.5	6.5
Jan.,	1986	2	233	0.3	1.5
Feb.		3	57	0.2	0.8
Mar.		35	50	1.7	7.8
Apr.		13	55	0.8	3.4
Total		471		22.3	100.0

1) Within the period, forages were harvested.
2) Proportion of leached potassium in the month to the total amount in a year.

It was thought that there might be K leaching on the grassland soil from the result of the *experiment 1*, with the fact of the difference in the exchangeable soil K content between the soil layers.

Table 1 shows the K leaching from the lysimeter. During a year from May, 1985 to April, 1986, the volume of leached water from the lysimeter was about 471 liters/m^2. The amount of leached water was influenced by the precipitation as shown in Fig. 1. The quantity of leached K was 22.3 g/m^2 during the investigation. There was a decreasing tendency of K concentration with the increase of volume of leached water among sampling dates, but the concentration was not significantly different except on Jan. 1986 when the water volume was the least during the experimental period. Therefore, the amount of K leached depended

Table 2. Seasonal changes of dry matter production, forage potassium content, potassium uptake by plants, exchangeable potassium contents and amount of K fertilization in the lysimeter

Sampling date	DM yield Or 5) (g DW/m^2)	DM yield WC 6) (g DW/m^2)	Plant K 1) Or (mg/g DW)	Plant K 1) WC (mg/g DW)	K uptake 2) Or+WC (g/m^2)	Exchangeable soil K 3) (mg/100 g)	Fertilized K 4) (g/m^2)
Jul. 17, 1985	147	28	44	42	7.6	15 ± 2 (3)	17.5
Oct. 8	138	5	44	32	6.2	45 ± 4 (3)	26.2
Dec. 3	145	19	44	37	7.0	40 ± 0 (2)	13.1
Apr. 29, 1986	780	40	50	47	40.8	19 ± 6 (2)	10.5
Total					61.6		67.3

1) Value of one sample.
2) Obtained by multiplying plant K by DM yield.
3) Mean ± S.D. of number in parenthesis.
4) Fertilizer was applied for the forage growth before the sampling date.
5) Or; orchardgrass.
6) WC; white clover.

mainly on the volume of leached water. About 40 % of K in a year leached out during the first two months, May and June, after the start of the experiment. On the other hand, leached K amounted to 13.2 g/m^2 during the period from July, 1985 to April, 1986, when surface soil of the lysimeter became more solid and forages more advanced in a viewpoint of growth stage than those on May and June. These results had a similar tendency with that of Mengel and Kirkby (1978). They described that leaching rate of K from a clay loam soil was higher in the fallow than in the cropped treatment, and suggested that leaching is especially low under permanent grassland.

Table 2 shows the seasonal changes of dry matter (DM) production, forage K content, K uptake by plants, exchangeable soil K content and amount of K fertilization in the lysimeter. Both DM production and K uptake were somewhat more than those on orchardgrass meadow, but the forage K and the exchangeable K contents of the soil in the lysimeter showed similar tendency with those obtained on K-medium plot (Kim, 1988). Most of fertilized K was absorbed by plants, and K taken by plants was 61.6 g/m^2.

With removal of K by forage crops, K leaching from soil was also crucial point to the K nutrition of forage crops. Potassium leached about 22.3 g/m^2/yr from the lysimeter, but the value on the present experiment was significantly greater than the data observed in Germany, which extended from 0 to 1.7 g/m^2/yr (Mengel and Kirkby, 1978). And the ratio of leached K to K uptake by forages was 21 %, and greater than the value of 13 % (Bonner and Galston, 1952). Because the soil of the lysimeter basin was dug and filled with new soil, the value presumably was estimated greater than the real value in a grassland condition. But in the meadow of *experiment 1*, rain water could not percolate easily with such a high degree of soil hardness on the soil surface.

And the fact of much amounts of K leached at first two months of rainy season suggests the necessity of the selection of seasons for artificial interruption of grassland such as cultivation, establishment and renovation. These facts suggest that deep plowing in the humid region results in considerable K loss and makes it necessary to fertilize much K (Foth, 1978).

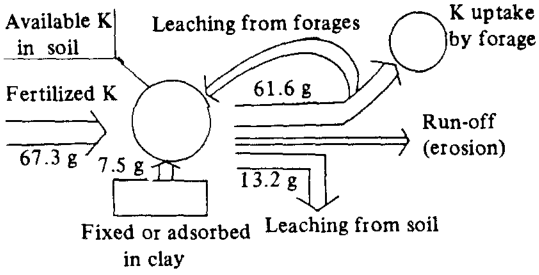

Fig. 4. Potassium flow in the lysimeter.

The K flow in the lysimeter experiment can be drawn as Figure 4. In the flow, the amount of K released from the non-exchangeable soil K was estimated 7.5 g/m^2. Basically, most of the K in soils is in minerals and a part of it is eroded and released as K ions. The ions are adsorbed on the cation exchange and are readily available for plant uptake (Foth, 1978). However, K leaching from living forages might have been included in the estimated value. As previously reported by Kim et al.(1986) the ratio of extractable K under submerged condition ranged 2.7-10.4 % of total K contents of the forages, and the relative amounts of K in the dead forage decreased rapidly to 40 %, sometimes even to 3 % of the initial amount in the first month of leaching on soil surface of meadow (Kim et al., 1989). Potassium under permanent grassland seems to act efficiently and repeatedly with less K leaching from soil because of higher soil hardness and with K leaching from the forages into the soil. But exact amounts of released K from non-exchangeable soil K and leached K from living forages were not determined in the present experiment.

IV. SUMMARY

In this report two experiments were carried out. Vertical distribution of exchangeable potassium(K) of soil in the orchardgrass meadow was investigated, and K leaching from soil was monitored under lysimeter condition throughout one year. The results obtained are as follows;

The difference in the exchangeable soil K content between the soil layers was very small in K-zero plot of the orchardgrass meadow, but it was significant in K-high plot (*Experiment 1*).

The volume of leached water from the lysimeter was about 471 liters/m^2 during a year and the amount of leached water was influenced by the precipitation. During the investigation the quantity of leached K was 22.3 g/m^2. About 40 % of the total K in a year leached out during the first two months, May and June, after the start of the experiment. On the other hand, leached K amounted to 13.2 g/m^2 (60 % of the total K leached) during the period of ten months from July, 1985 to April, 1986, when forages were harvested from the soil of the lysimeter (*Experiment 2*).

From the above results, it was known that K leaching from grassland soil can be also occurred in considerable amount when the growth stage of forage is not developed or soil does not become solid on such a period as immediately after grassland improvement or establishment. However, unless the K leaching from soil seems to be little under the condition of permanent grassland ecosystem with higher grade of soil hardness and possibly with compact density of forage plants.

ACKNOWLEDGEMENTS

The first author is indebted to Mr. H. Kubota, a retired technician of Nagoya University Farm, for his kind help during the study and the authors are thankful to Dr. M. Ohshima, a professor of Nagoya University, for his help in preparing the manuscript in English.

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