飼料作物栽培に関する沖縄土壌の施肥管理 : II. 暗赤色土におけるローズグラスのカリ施用に対する反応(農芸化学科)

Fertilization Management of Okinawan Soils for the Cultivation of Forage Crops

II. Response of Rhodesgrass to potassium application on a Dark Red soil

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Summary

On the Dark Red soil at the University Farm, Rhodesgrass (*Chloris gayana* Kunth, Culti. var. ELMBA) was grown for a year from March, 1982 and cut 6 times, during which potassium (K_2O) was applied at the varied rates of 0, 50 and 100 kg/ha/cut with a constant rate of N and P_2O_5.

There was no significant difference in the grass yield that ranged from 13 to 14 tons (d.w.)/ha in the total of 6 cuts. From the data obtained on the yield and potassium absorption of the grass and the potassium level of the soil after the 6th cut, it was deemed that application of about 50 kg of K_2O/ha/cut was pertinent on the tested soil.

The concentrations of potassium, calcium and magnesium of the grass tended to vary with the cutting season but not much with the application of potassium. Simple correlations between percent K_2O and milliequivalent ratio of K/(Ca+Mg) of the grass were significantly positive in most of the cases.

Exchangeable magnesium tended to decrease in the soil by the cultivation of the grass. Available phosphate increased in the soil for 100 kg of P_2O_5/ha/cut was applied. One of the merits in the cultivation of Rhodesgrass was the addition of organic residues to the soil.

Introduction

It is a general requirement to obtain yields of high quality forage crops as much as possible in making an efficient use of resources including soil and fertilizers. To meet this requirement, fertilization management is considered essential in maintaining and even improving soil fertility.

In the previous paper one of the authors reported that potassium application showed favorable effects on the yield and potassium absorption of Sudangrass in some of Okinawan soils under the greenhouse conditions[5]. However, conditions in the field were ordinarily expected to be different from those in the greenhouse.

The objectives of the present report were to investigate (1) response of Rhodesgrass to potassium in the field condition, (2) contents and balance of potassium, calcium and magnesium of the grass, and (3) effects of Rhodesgrass cultivation on soil fertility in relation to potassium fertilization

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on a Dark Red soil of Okinawa.

Materials and Methods

Rhodesgrass was used for the investigation, because it is monocotyledon and belongs to graminea family with Sudangrass, which was used in the previous investigation[5]. And, because of its high adaptability to the climate and soils of Okinawa, it is now widely grown as one of the important forage crops in Okinawa since it was introduced here.

Rhodesgrass (*Chloris gayana* Kunth, Culti. var. ELMBA) was grown in the University of the Ryukyus Experiment Farm №17 of Dark Red soil. Cation exchange capacity of the soil sampled as described later ranged from 14 to 17 me/100g, and total nitrogen was 0.12 to 0.13%. The texture was heavy clay containing more than 45% of clay. Clay mineralogy was assumed to be consisting mainly of vermiculite-chorite intermediate, illite and kaolinite, according to the data obtained in the soil nearby[6]. Other chemical properties of the soil were shown in Table 1.

Table 1. Chemical properties of the soil before and after the experiment of potassium application*

Fertilizer treatment plots	pH (H_2O)	Exchangeable bases (me/100g)				Total C (%)	Available phos. (mg P_2O_5/100g)
		Ca	Mg	K	Na		
			Before the experiment				
A (10-10-0)	5.6±1.4	5.4±4.2	0.9±0.3	1.0±0.3	0.09±0.05	0.93±0.25	1.7±0.5
B (10-10-5)	5.8±0.8	5.8±3.3	0.9±0.4	1.0±0.4	0.14±0.09	1.05±0.29	1.4±0.1
C (10-10-10)	6.0±1.5	8.5±9.0	0.5±0.3	0.9±0.2	0.11±0.08	1.04±0.23	1.4±0.3
			After the experiment				
A (10-10-0)	5.4±0.1	10.5±3.9	0.4±0.3	0.3±0.2	0.06±0.01	1.07±0.17	8.8±3.3
B (10-10-5)	4.9±0.2	5.5±0.5	0.2±0.2	0.7±0.4	0.06±0.03	1.25±0.35	9.4±4.4
C (10-10-10)	5.2±0.6	7.1±2.7	0.4±0.2	0.8±0.3	0.05±0.01	1.15±0.09	7.1±2.1

* Values are means and standard deviations of three replicates.

The fertilizer treatment plots were set in that pasture of Rhodesgrass, which was sown in June, 1981 and cut 4 times, including the cleaning cut for this experiment in March, 1982. The variable in the fertilizer treatment was the amounts of potassium, namely 0, 50 and 100 K_2O/ha/cut, with a constant amount of nitrogen (100 kg N/ha/cut) and phosphate (100 kg P_2O_5/ha/cut). Accordingly, respective application rates were 10-10-0, 10-10-5 and 10-10-10. The source of the elements were ammonium sulfate for N, superphosphate for P_2O_5, and potassium chloride for K_2O. The plot was 32.5 m² (6.5m×5m), replicated three times and arranged in the way of Latin Square.

After the grass was cut in March, 1982 for cleaning purpose, the soil was sampled for analysis from each plot at the depth of 0 to 10 cm, and fertilizers were broadcasted after liming to the plots with pH values lower than 5.0. Fertilizers were given after every cut for harvest. The grass was cut 6 times by Feb, 1983 in the intervals of 44 to 62 days except for the 6th cut, which took 72 days, and weighed to determine the yield.

Samples of the grass were collected at the 2nd, 4th and 6th cuts for chemical analysis. Soil samples were also collected after the 6th cut in the same way described above to compare analysis with those obtained before the experiment of potassium application. Litter was collected from the soil surface and roots plus stubble were collected from the depth of 0 to 20 cm after the 6th cut.

Results and Discussion

(1) Yield of the grass

The yield of the Rhodesgrass plant, determined as fresh weight, were shown in Table 2. The total fresh yields of 6 cuts ranged from 67 to 76 tons per hectare. Significant difference was not found among the potassium treatments when analysis of variance was done on the total fresh yields.

The dry matter yields of the respective cuts were compared and shown in Fig. 1. Much difference among the treatment was not found in the dry matter yield of the 1st cut. This was highly attributable to the previous fertilizations where the fertilizers of 14-5-8 were used and the potassium left over affected the yield of the 1st cut in this experiment. The potassium status of the soil, shown in Table 1, indicates that the soil contained about 1 me of exchangeable K per 100g soil before this experiment. The dry matter yields of the 3rd and 4th cuts were lower than that of the 5th cut. The air temperature ranged from 17 to 29°C during the experiment, was over 20°C from April to November, and over 25°C from June to September. The grass of the 2nd and 3rd cuts grew under favorable conditions as far as the temperature was concerned. But the rainfall was unusually high in June and unusually scarce in July. These unfavorable conditions of moisture might have resulted in the lower yields of the 2nd and 3rd cuts. If the moisture conditions were pertinent for these 2 cuts, yield differences might have been obtained as those in the 4th cut, which showed the highest dry

Table 2. Yields of Rhodesgrass in fresh weight as affected by potassium application

Cut number	Date of cut	K_2O applied, Kg/ha[a)		
		0	50	100
		Fresh weight yield, t/ha[b)		
1	May 18, 1982	14.30	15.90	16.57
2	Jun 30, 1982	13.00	12.93	12.93
3	Aug 17, 1982	10.83	11.47	11.00
4	Oct 14, 1982	11.27	14.13	12.37
5	Dec 9, 1982	7.47	9.67	9.17
6	Feb 18, 1983	10.10	11.73	10.77
Total		66.97	75.83	72.81

a) Potassium was applied after respective cuts with a constant rate of N and P_2O_5.

b) Values are means of three replicates.

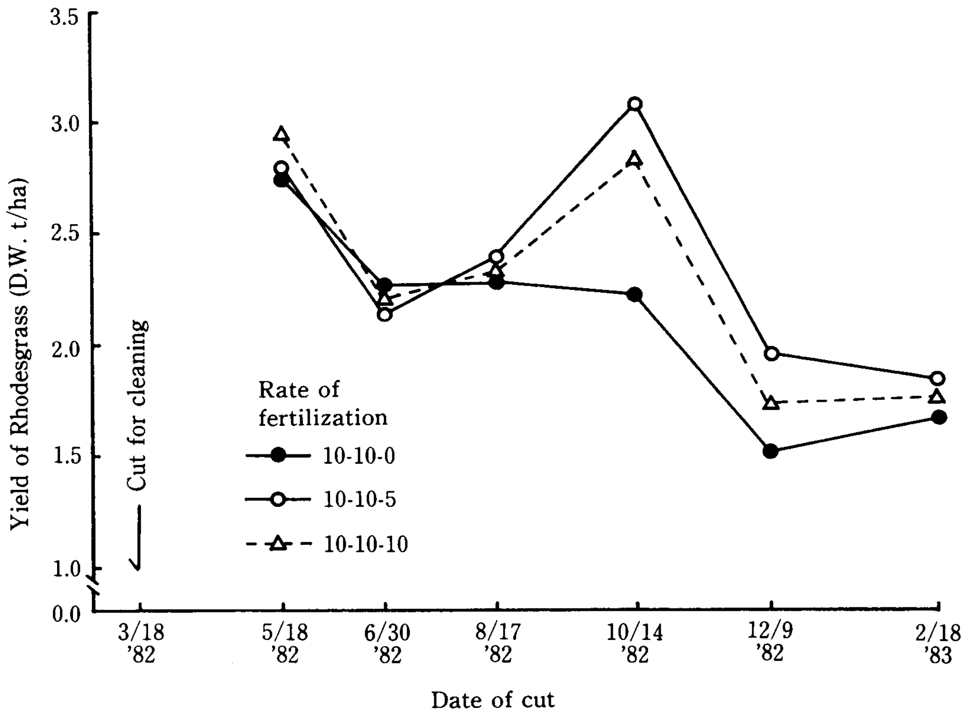

Fig. 1. Yields of Rhodesgrass at respective cuts as affected by potassium application

matter yield with the 10-10-5 treatment and the lowest with the 10-10-0 treatment. Even lower yields of the 5th and 6th cuts were considered as an unfavorable effect of the temperature lower than 20°C. In these cuts, the highest yields were still obtained with the 10-10-5 treatment and the lowest with the 10-10-0 treatment.

The total dry matter yields of 6 cuts were 13.18, 14.20 and 13.78 tons per hectare in the 10-10-0, 10-10-5 and 10-10-10 treatments, respectively. Analysis of variance showed that there was no significant difference in the dry matter yield among the treatments. Consequently, it is deemed that potassium application does not give measurable effects on the yield of grass as far as nitrogen and phosphorus are applied at sufficient levels. It is known that atmospheric sodium originating from the seawater is supplied in the rainwater in the island environment of Okinawa[3,4]. And also believed is that sodium plays compensation effects for the growth of plants to some extent as stated elsewhere[1]. The growth of Rhodesgrass in the 10-10-0 treatment plots may have benefited from sodium in the rainwater, and declined not much without receiving potassium application. However, there were 3 in the 6 cuts that showed a tendency of higher yields with the 10-10-5 treatment and lower yields with the 10-10-0 treatment. Consequently, it may be reasonable to consider that the optimum amount of potassium application per cut is about 50 kg of K_2O per hectare at least for a year on the tested soil.

(2) Concentrations of potassium, calcium, and magnesium in the grass

The Rhodesgrass samples of the 2nd, 4th, and 6th cuts were analyzed for such basic minerals as potassium, calcium, and magnesium, and also milliequvalent ratios of K/(Ca+Mg) in the plant material were calculated as shown in Table 3.

Table 3. Potassium, calcium, and magnesium concentrations and milli-equivalent ratio of potassium to calcium plus magnesium in Rhodesgrass

K_2O application, kg/ha	K_2O %	CaO %	MgO %	K/(Ca+Mg) me
		2nd cut		
0	3.70±0.49	0.55±0.10	0.17±0.04	2.90±0.93
50	4.13±0.60	0.60±0.01	0.22±0.06	2.73±0.23
100	4.11±0.10	0.58±0.02	0.21±0.05	2.84±0.19
		4nd cut		
0	3.01±0.29	0.50±0.05	0.28±0.06	2.07±0.41
50	3.04±0.16	0.47±0.07	0.25±0.03	2.26±0.34
100	2.91±0.35	0.53±0.04	0.25±0.05	2.03±0.48
		6nd cut		
0	2.76±0.79	1.06±0.13	0.48±0.07	0.98±0.34
50	3.48±0.55	1.00±0.06	0.43±0.06	1.31±0.26
100	3.31±0.35	0.97±0.07	0.41±0.07	1.30±0.29

The concentrations of K_2O, CaO, and MgO ranged from 2.8 to 4.1%, 0.47 to 1.06% and 0.17 to 0.48% in the tissue, respectively. These mineral concentrations varied mainly by the cutting season rather than the potassium application.

The concentration of potassium tended to decrease in the 10-10-0 treatment as the cutting advanced, and instead the magnesium concentration tended to increase. This occurrence may be reasonable, because of the antagonistic relationship between potassium and magnesium in absorption by plants. However, the grass in the other treatments also increased in the concentration of magnesium with advancement of cutting without being accompanied by a decrease in potassium. The cause of this observation should be studied in the future.

In order to see the mineral balance in forage crops, the milliequivalent ratio of K/(Ca+Mg) is taken into consideration[2]. The obtained ratios ranged from 1.0 to 2.9 in most cases of the present investigation. Significant difference in the K/(Ca+Mg) ratio was not recognized among the

Table 4. Simple correlations between percent K_2O and milliequivalent ratio of K/(Ca+Mg) in Rhodesgrass

Grass and number of treatment	Simple correlation between % K_2O and K/(Ca+Mg) in m. e.
2th cut (n=9)	r=0.524
4th cut (n=9)	r=0.734*
6th cut (n=9)	r=0.954**
Total(n=27)	r=0.673**

* and ** denote the significant levels at 1% and 5%, respectively.

treatments. Simple correlations between percent K_2O and K/(Ca+Mg) were shown in Table 4. The correlations were significant in most of the cases except for the 2nd cut. Critical balance of these elements in Rhodesgrass must be studied in the future, since it is stated that cattles may suffer from a disease so called grass tetany when the grass of high potassium concentration and K/(Ca+Mg) ratio is fed to the cattles[2].

(3) Potassium absorption of the grass

The quantity of potassium absorbed by the Rhodesgrass plant was calculated from the concentration of K_2O and the yield of dry matter, and shown in Fig. 2. There was no significant difference in the potassium absorption of the grass among the treatments. In the treatment plots of 10-10-0 and 10-10-5, more potassium was absorbed than applied, and less potassium than applied in the 10-10-10 treatment, where the potassium applied was not efficiently utilized by the grass.

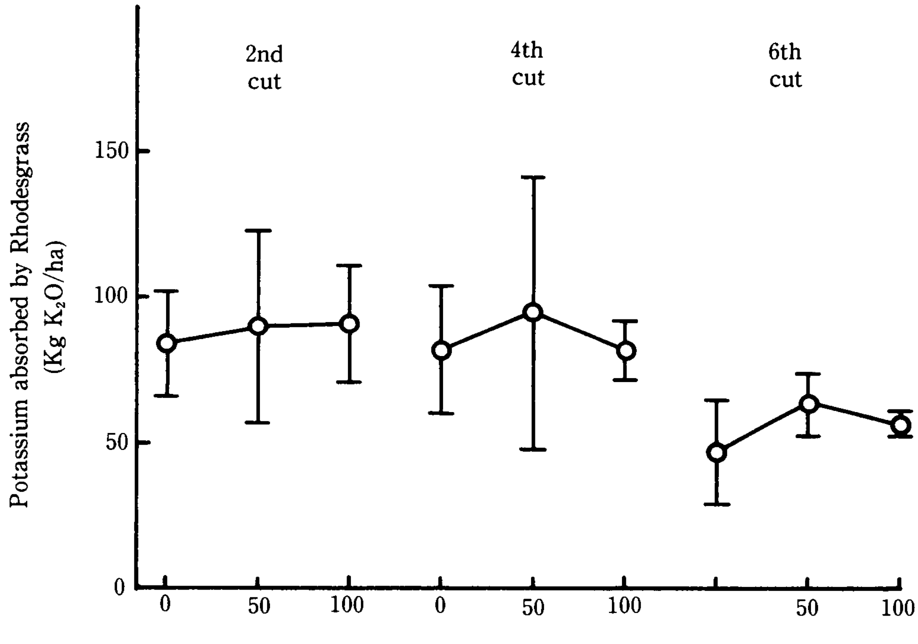

Fig. 2. Potassium absorption of Rhodesgrass of the 2nd, 4th, and 6th cuts as affected by potassium application (The vertical bars indicate standard deviations of 3 replicates.)

(4) Litter and roots plus stubble

The dry weights of litter and roots plus stubble were measured after the 6th cut and the result was shown in Fig. 3. The litter yields were lower in the A treatment (10-10-0) and higher in the B treatment (10-10-10), ranging from 2.8 to 5.3 tons of dry weight per hectare. The weight of roots plus stubble, on the other hand, was higher in the A treatment and lower in the C treatment, ranging from 4.5 to 3.0 t/ha. Totale of the litter and roots plus stubble ranged from 7.3 t/ha in the A treatment to 8.3 t/ha in the B and C treatments. In the future it must be studied on what caused an increase

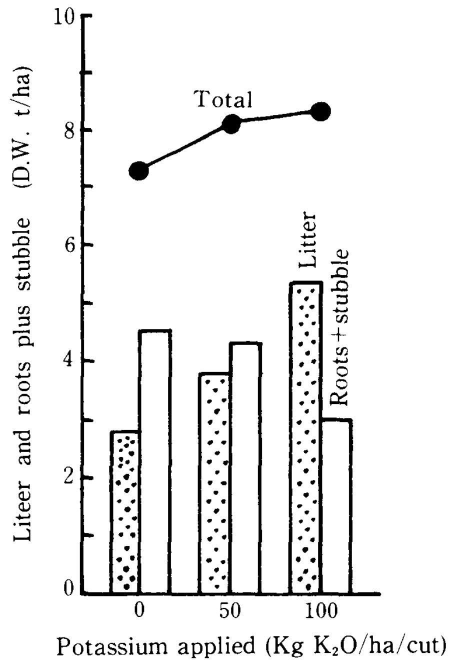

Fig. 3. Litter and roots plus stubble of Rhodesgrass plant received various amounts of potassium

in the litter and a decrease in the roots plus stubble as the potassium application increased. Namely, the estimated numbers of stubble were 2.6 ±1.4 per a quadrate of 50 cm×50 cm, being equivalent to 104,000±56,000 per hectare.

The organic residues amounted to about 35 to 40 t/ha of green manure when the litter and roots plus stubble were converted to plant materials with 80% moisture.

(5) Soil fertility before and after the experiment

Soil samples were collected before this fertilization experiment and after the 6th cut of the grass. Some of chemical properties of the soil were analyzed as a measure of fertility and shown in Table 1 for comparison.

Exchangeable bases such as magnesium and sodium tended to decrease in the soil by the cultivation of Rhodesgrass. The decrease in these nutrient elements was evidently attributable to the absorption by the grass. A remarkable decrease in potassium was noticed only in the A treatment which did not receive any application of potassium. In the C treatment which received 100 kg of K_2O/ha/cut, exchangeable potassium did not increase in the soil. This was the indication that some of applied potassium was lost by leaching, because potassium absorbed by the grass was less than that applied on these treatment plots as shown in Fig. 2, and the Dark Red soils were regarded poor in potassium retention[5)].

About pH and exchangeable calcium in the soil, an increase or decrease caused by growing the grass was not recognizable from the analytical data, because the experiment plots with a lower pH value received liming after collecting the soil samples for analysis.

Inspite of the fact that total carbon did not increase to a noticeable extent, the available phosphate determined as 0.002 N H_2SO_4 soluble forms increased remarkably in the soil by the cultivation of Rhodesgrass and fertilization. The soil receiving 600 kg of P_2O_5 for 6 cuts in about a year may have resulted in the improvement of phosphate fertility.

Conclusion

The fresh yield of the aerial parts of Rhodesgrass ranged from 67 to 76 t/ha, and dry matter from 13 to 14 t/ha for 6 cuts from March, 1982 to February, 1983, during which potassium (K_2O) was applied at the rates of 0, 50 and 100 kg/ha/cut. In the yield of the grass, difference was not found among the treatments. The yields on the 10-10-5 treatment (100 kg of N and P_2O_5, and 50 kg of K_2O/ha/cut) still tended to be the highest in 3 out of 6 cuts.

The concentration of potassium (K_2O) in the grass ranged from 2.8 to 4.1%, calcium (CaO) from 0.04 to 1.06% and magnesium (MgO) from 0.17 to 0.40%. These concentrations varied by the cutting season rather than the potassium application. Milliequivalent ratio of K/(Ca+Mg) ranged from 1.0 to 2.9, and simple correlations between K_2O% and K/(Ca+Mg) ratio in the grass were significantly positive in most of the cases. Necessity of studying the balance of potassium, calcium and magnesium in the Rhodesgrass plant was emphasized in connection with a disease of cattle so called grass tetany.

Potassium absorption of the grass calculated on the 2nd, 4th, and 6th cuts varied with the cutting season. In general, the grass absorbed more potassium than that applied in the 10-10-0 and 10-10-5 treatments and less than that applied in the 10-10-10 treatment.

The dry weight of litter ranged from 2.8 t/ha in the 10-10-0 treatment to 5.3 t/ha in the 10-10-10 treatment as determined after the 6th cut. A reverse relation was found in the roots plus stubble, ranging from 4.5 t/ha in the 10-10-0 treatment to 3.0 t/ha in the 10-10-10 treatment. The totals of the litter and roots plus stubble were 7.3 t/ha in the 10-10-0 treatment and 8.2 t/ha in the 10-10-5 and 10-10-10 treatments.

The soil analysis, which was done on the samples taken before and after the potassium application experiment, showed a decrease in exchangeable magnesium and sodium in the soil as affected by growing the grass. A decrease in exchangeable potassium was evident only in the 10-10-0 treatment. The soil of 10-10-10 treatment did not show any increase in exchangeable potassium although the grass on this treatment absorbed less potassium than applied. The discrepancy was considered as the loss of applied potassium possibly caused by leaching. The soil on the other hand remarkably increased in available phosphate.

It was deemed from the data obtained that about 50 kg of K_2O/ha/cut would be the pertinent amount to apply in cultivating Rhodesgrass on the tested Dark Red soil at least for a year. From the soil fertility point of view, the cultivaiton of Rhodesgrass was considered favorable on a point that it gave the soil a quantity of organic residues.

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飼料作物栽培に関する沖縄土壌の施肥管理
II. 暗赤色土におけるローズグラスのカリ施用に対する反応

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摘　要

本研究は暗赤色土（通称島尻マージ）におけるカリ施用に対するローズグラス（*Chloris gayana* Kunth, Culti. var. ELMBA）の反応，カリ施用に伴うローズグラスのカリ，カルシウム，マグネシウムの吸収及び土壌肥沃度に及ぼすローズグラス栽培の影響などを圃場条件下で調べることを目的とした。

ローズグラスは農学部附属農場No.17圃場（暗赤色土）で栽培されているものを用いたが，このローズグラスは1981年6月に播種，1982年3月の掃除刈を含め4回の刈取りが行われた。掃除刈後のローズグラス草地に，10a当たりN，P_2O_5，K_2O 施用を10-10-0（A区），10-10-5（B区）、10-10-10（C区）とする試験区を設けた。試験区は32.5m²（6.5m×5m）の3連とし，配置はラテン方格法とした。カリ施用試験開始後44～72日間隔で刈取りを行い，1983年3月までに6回刈取った。その間刈取り毎に前記量の肥料を全面施用した。掃除刈後第1回施肥までの間に各区から採取した土壌（0～10cm）を実験前土壌とし，第6回刈取り後に採取した土壌を実験後土壌とし，各々の分析結果をTable 1に示した。

ローズグラスの青刈収量はTable 2に，乾物収量はFig.1に示した。1982年6月は多雨，7月は旱ばつであったことが第2回及び第3回刈取草に影響し低収量となった。

乾物収量は6回刈取のうち3回はB区で高い傾向がみられたが，6回刈取りの合計はA区1.32t，B区1.42t，C区1.38t/10aとなりカリ施用による有意差は認められなかった。

ローズグラスのK_2O, CaO, MgO含有率はそれぞれ2.8～4.1%，0.47～1.06%，0.17～0.48%であった(Table 3)。この含有率はカリ施用より，刈取季節により変動する傾向がみられた。またK/(Ca+Mg)当量比は殆ど1.0～2.9の範囲にあり、K_2O%とK/(Ca+Mg)の関係は正の相関を示す場合が多かった(Table 4)。

ローズグラスのカリ吸収量はA区及びB区においては施肥量以上，C区においては施肥量以下という傾向が示された（Fig.2)。

第6回刈取り後に測定したリッター，根，刈株などの乾物総量はA区0.73t/10a，B区とC区でそれぞれ0.82t/10aであった(Fig.3)。これは有機物として3.5～4.0t/10aの緑肥に相当する量であり土壌肥沃度に好影響が期待される。

カリ施用栽培前後の土壌化学性を比較すると，交換性マグネシウムとナトリウムは全体的に減少し，カリは無施用区（A区）においてのみ減少した。C区においてはローズグラスのカリ吸収が施用量以下であるにもかかわらず土壌カリの増加がみられないことから，施用カリが溶脱損失していると考えられた。可給態リン酸は施肥の影響を受け，全区とも著しく増加した。

以上より供試暗赤色土におけるローズグラス栽培では，刈取り毎のカリ(K_2O)施用適量は約50kg／10aであろうと推定された。またローズグラス栽培によりかなりの有機残渣が賦蓄され土壌肥沃度に好影響を与えると考えられた。

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