OCTOBER, 1952 RESEARCH BULLETIN 510

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

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POTASSIUM-BEARING MINERALS AS SOIL TREATMENTS

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Publication Authorized October 1, 1952

COLUMBIA, MISSOURI

ACKNOWLEDGMENT

Acknowledgment is gladly made to J. I. Rodale, Soil and Health Foundation, Emmaus, Pa., for the financial support and encouragement of this study. Also the cooperation of Professor W. D. Keller, Department of Geology, University of Missouri, is gladly acknowledged.

This investigation was conducted under Department of Soils project number 51-b, "Relation of the Primary Mineral Reserve to the Available Nutrients and Uptake by Plants."

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INTRODUCTION

The acidity in the soil, created by the plant roots (and by the soil microbes), is Nature's chemical reagent for processing the rock and mineral fragments there much as we process rock phosphate with sulfuric acid. This root acid converts their contents of unavailable nutrient elements into forms more readily available for plant and microbial nutrition. While the clay separate of the soil is the intermediary between the root and the silt-sized mineral fragments; and while it is the clay that carries the stock of nutrients we measure when testing soils for their "available" supplies of these; it is the finely ground mineral and rock particles serving as the reserve fertility from which the clay is restocked. The clay is the means of passing the acid from the roots to the minerals and, in turn, the nutrients in the reverse direction, or from the mineral fragments to the plant roots. The nutrients held on the clay are the "starter" fertilizer for a single crop. It is these reserve minerals—mixed with the clay—as the soil skeleton that are the sustaining fertility for many crops over many years.

It is significant, therefore, in our research in soils that (a) an inventory be taken of the reserve minerals in a soil, and (b) that we get some conception of the rate of mineral conversion from the more insoluble to the more available forms of these natural reserves—and of any applied to the soils—in relation to the nutrition of our crops.

It was the aim of the study reported here to use potassium-containing minerals as soil treatments and to measure the rates at which they deliver their potassium contents to a growing crop during successive cuttings or during interrupted growth. There were ten different minerals. They were finely ground and used as soil treatments for the growing of Ladino clover. By means of chemical analysis of the harvested crop, measurements were made of the potassium delivered from the different minerals in comparison with such deliveries from this soil receiving no potassium, and the like soil given this nutrient in the form of the more soluble carbonate and chloride salts.

PLAN AND METHOD OF THE INVESTIGATION

The Ladino clover was grown on soil treated with the various finely ground mineral materials as a source of potassium for the plants. The soil was a silt loam, moderately deficient in potassium. The characteristics as revealed by simpler soil tests (1)* are given in Table 1. The soil was brought to the greenhouse, carefully dried and screened for mixing with the various chemicals supplying amply the nutrients other than potassium. Soil amounting to 7000 grams for each pot was weighed out. To this amount the following mate-

Table 1. Test Results of the Soil Used.

Organic matter	2.0%
P_2O_5 (Bray's extract)	60 pounds/acre
pH	6.6
Exchange cations - m.e./100 gms.	
Hydrogen ----- 2.0	
Calcium ------ 9.5	
Magnesium --- 1.0	
Potassium ---- .18	

terials were added, in equivalents, as respective pounds per two million pounds of soil; rock phosphate 1000 pounds; superphosphate 100 pounds; ammonium nitrate 130 pounds; magnesium sulfate 50 pounds; copper sulfate 30 pounds; sodium borate 30 pounds; manganese sulfate 30 pounds; zinc acetate 5 pounds; and sodium molybdate 5 pounds. The amount of potash (K_2O) estimated as a suitable application in this study was 220 pounds per two million pounds of soil. The potash content of the mineral feldspar, for example, is 11 per cent. Therefore, if one is to make an addition of 220 pounds of potash per acre in the form of feldspar then 2000 pounds of this mineral must be used. All the mineral treatments for potassium were made on the equivalent basis of this application of potash per acre. The pots were set up triplicate; three were left as check pots without potassium treatment. The soils were then brought to optimum moisture by using distilled water and were seeded with Ladino clover.

Minerals Tested

In the first series of pots the following chemical salts and minerals were tested: potassium carbonate and potassium chloride as salts; and orendite pumice, orendite, illite, alunite, glauconite, granite, basalt, Wyomingite, feldspar, and rhyolite as the minerals. Sam-

*Numbers in parentheses refer to items in the literature cited, page 2.

ples of illite, alunite, and glauconite were calcined at a temperature of 400°C. and used as additional soil treatments. At a later date soil cultures containing illite, glauconite, alunite, and a feldspar-dolomite mixture, each calcined at 700°C. were added to the plan of the experiment. The chemical analyses of the original minerals (4) tested are reported in Table 2, and the spectrographic analyses in Table 2a.

Methods of Analysis of the Clover

Harvests of the plants were taken after successive growing intervals of 68, 39, 56 and 95 days, or a total growing time of 258 days. These harvested plants were oven-dried (60°C.), weighed, and recorded. Oven-dry samples of two grams of material were ashed over night at a temperature below 500°C. and allowed to cool. Then 2 ml of perchloric acid (70%) were added and brought to boiling. After all the carbon had disappeared the perchloric acid was evaporated to near dryness, after which the samples were taken up with distilled water and filtered into volumetric flasks. Analyses for potassium and calcium were carried out by methods using the flame photometer (3). The magnesium was determined by the methods outlined by Sturgis and MacIntire (2).

RESULTS OF CHEMICAL ANALYSES

The analytical data representing the mean values of the triplicates for the total plant material are given in Tables 3-8, inclusive. In order to make comparison of the potassium delivered by the four successive cuttings more simple, the data of Table 7 are also presented graphically by Figures 1-4, inclusive.

From the data it is evident that the calcining of the minerals made their potassium more readily available. Also, there were pronounced differences in the amounts of potassium delivered to the crop by the different minerals applying equal amounts of potassium to the soil. Also it is evident that in many cases these minerals were undergoing transformation as a result of incorporation into the soil, resulting in the additional amounts of potassium going to the crop. It is evident that in this soil with a degree of acidity no more severe than that represented by a pH of 6.6, the reaction rate between this soil growing the crop and the various minerals was rapid enough to provide significant amounts of potassium in the cases of some of the samples used. In others, the rate was not rapid enough for the growth period as long as 258 days to represent potassium release of significance so far as uptake of this nutrient element by the clover plants would indicate. Nevertheless, this does not deny the possibility that over longer time intervals and higher degrees of hydrogen saturation of the clay, these less active potassium-bearing minerals

Table 2. Chemical Composition of the Different Minerals Used as Soil Treatments.

		Illite	Glauconite	Rhyolite	Granite	Wyomingite	Orendite Pumice	Feldspar	Orendite	Basalt	Alunite
Silica	SiO_2	51.47	45.71	72.88	67.33	50.94	53.61	63.19	50.09	43.77	0.69
Alumina	Al_2O_3	19.43	7.21	11.49	18.51	13.14	12.96	22.32	12.76	16.23	36.40
Ferric Oxide	Fe_2O_3	6.58	22.95	3.46	1.78	5.51	4.50	0.81	5.15	18.52	0.38
Titania	TiO_2	1.01	0.98	0.39	0.38	2.43	2.70	0.31	2.57	2.92	0.20
Magnesium Oxide	MgO	1.75	2.75	0.67	0.41	7.08	5.45	0.07	7.31	3.69	0.64
Calcium Oxide	CaO	1.23	1.80	0.40	2.63	6.80	3.73	0.35	6.13	8.13	0.30
Potassium Oxide	K_2O	4.66	8.25	8.45	3.96	9.19	10.76	7.47	9.69	2.59	8.95
Sodium Oxide	Na_2O	1.65	0.48	1.38	3.60	0.49	3.38	3.58	2.04	2.87	0.42
Ignition Loss above 105°C.		5.65	6.51	0.64	1.20	2.67	2.11	1.51	2.46	None	15.83
Moisture dried at 105°C.		3.09	2.97	0.01	0.14	0.40	0.32	0.01	0.42	0.30	0.17
Manganese Oxide	MnO_2	0.12	0.01	0.12	0.12	0.35	0.24	0.24	0.35	0.47	0.01
Sulphur as Sulphur Trioxide	SO_3	3.12	0.38	0.10	0.01	0.58	0.24	0.01	0.57	0.27	36.05

Table 2a - Spectrographic Analyses of the Potassium-bearing Minerals Used as Soil Treatments (Supplement to Table 2)

Element / Sample	Cu	Co	Zn	Mo	Mn	Pb	Ag	B	Al	Na	Ca	Ni	Ti	K	Cr	V	Ba	Sr	Zr	Cd	Fe	Sn
Wyomingite	5^{-4}	3^{-4}	--	--	.03	5^{-4}	--	--	M	M	M	5^{-4}	.1	M	5^{-3}	3^{-3}	.02	.02	5^{-3}	--	.2	--
Orendite Pumice	5^{-4}	1^{-4}	--	1^{-4}	.01	5^{-4}	--	--	M	M	M	1^{-3}	.05	M	2^{-3}	1^{-3}	.01	.01	2^{-3}	--	.1	3^{-4}
Illite	1^{-3}	5^{-4}	5^{-3}	1^{-3}	.01	1^{-3}	1^{-4}	1^{-3}	M	M	m	5^{-4}	.05	m	1^{-3}	5^{-3}	1^{-3}	1^{-3}	--	--	1	5^{-4}
Feldspar	3^{-4}	--	--	--	3^{-3}	3^{-3}	1^{-4}	--	M	M	m	1^{-4}	1^{-3}	M	1^{-3}	2^{-3}	5^{-3}	5^{-3}	--	--	.05	--
Granite	5^{-4}	--	--	--	5^{-3}	2^{-3}	3^{-4}	--	M	M	M	3^{-3}	.02	m	5^{-4}	3^{-4}	2^{-3}	5^{-4}	--	--	.1	5^{-4}
Greensand	3^{-4}	3^{-4}	5^{-3}	2^{-4}	1^{-3}	1^{-4}	2^{-4}	5^{-3}	m	.01	m	5^{-4}	5^{-3}	m	5^{-3}	2^{-3}	1^{-3}	5^{-4}	--	1^{-3}	1	--
Rhyolite	1^{-3}	--	--	--	1^{-3}	3^{-4}	1^{-4}	1^{-4}	.01	.01	m	--	1^{-3}	5^{-3}	2^{-4}	5^{-4}	3^{-3}	5^{-4}	--	--	.1	--
Basalt	2^{-3}	1^{-3}	5^{-3}	5^{-4}	.05	1^{-3}	3^{-4}	1^{-4}	M	M	M	3^{-4}	.1	m	3^{-4}	2^{-3}	5^{-3}	5^{-3}	--	--	1	5^{-4}
Orendite	1^{-4}	3^{-4}	3^{-3}	1^{-4}	.03	1^{-3}	1^{-4}	--	M	M	M	2^{-3}	.05	M	5^{-3}	2^{-3}	.02	.01	5^{-3}	--	.3	2^{-4}
Alunite	5^{-4}	--	--	--	5^{-4}	1^{-4}	--	--	M	m	m	3^{-4}	1^{-3}	M	5^{-4}	2^{-3}	3^{-3}	5^{-3}	--	--	.05	--

Note: The results are expressed as approximate percentages, e.g. 5^{-4} represents 5 x 1^{-4}, or .0005 percent; M represents too much to be read; m represent less but still too much to be read.

The spectrographic analyses were made by using the D-C arc and cathode layer as a semi-quantitative method. The samples carried the following numbers in the records of the spectrographic laboratory in the order given S51-10-2, -3, -4, -5, -6, -7, -12, -13, -14, -15, and were recorded on plates Nos. 1420, 1424, 1434, 1435, 1438, and 1439.

Table 3. Yields and Concentrations of Potassium, Calcium, and Magnesium in the Dried Ladino Clover as the Result of Soil Treatments Using Different Potassium-bearing Minerals. (First Cutting - 68 days of growth)

Treatment	Average yield Dry weight gms.	Potassium %	Calcium %	Magnesium %
K_2CO_3	10.2	3.10	1.87	.23
KCl	10.9	3.02	1.69	.19
Orendite Pumice	9.4	2.35	2.23	.25
Orendite	13.2	1.78	1.91	.25
Illite (Cal. 400°C.)	11.6	2.10	1.87	.26
Alunite (Cal. 400°C.)	11.3	2.13	1.91	.21
Glauconite (Cal. 400°C.)	9.9	2.22	1.95	.23
Granite	11.2	1.85	1.87	.21
Alunite	10.9	1.91	1.91	.21
Illite	10.0	1.95	2.03	.25
Basalt	11.1	2.00	1.65	.23
No Treatment	8.8	2.00	1.98	.25
Wyomingite	10.1	1.78	1.87	.31
Glauconite	9.1	1.97	1.91	.21
Feldspar	8.8	1.81	1.95	.23
Rhyolite	10.8	1.50	1.91	.25

Table 4. Yields and Concentrations of Potassium, Calcium, and Magnesium in the Dried Ladino Clover as the Result of Soil Treatments Using Different Potassium-bearing Minerals. (Second Cutting - 39 days of growth)

Treatment	Average yield. Dry weight gms.	Potassium %	Calcium %	Magnesium %
K_2CO_3	10.0	2.10	1.50	.07
KCl	9.6	1.67	1.65	.07
Orendite Pumice	4.3	1.87	1.65	.21
Orendite	7.9	1.00	1.62	.14
Illite (Cal. 400°C.)	7.2	1.07	1.65	.13
Alunite (Cal. 400°C.)	6.7	1.02	1.76	.12
Glauconite (Cal. 400°C.)	6.0	1.12	1.50	.12
Granite	7.6	.85	1.76	.10
Alunite	4.8	.98	1.50	.12
Illite	4.5	.93	1.57	.11
Basalt	4.2	.78	2.03	.14
No Treatment	8.1	1.02	2.03	.08
Wyomingite	5.6	.85	1.62	.21
Glauconite	5.2	1.12	1.57	.11
Feldspar	5.1	.93	1.57	.19
Rhyolite	4.0	.90	1.54	.27

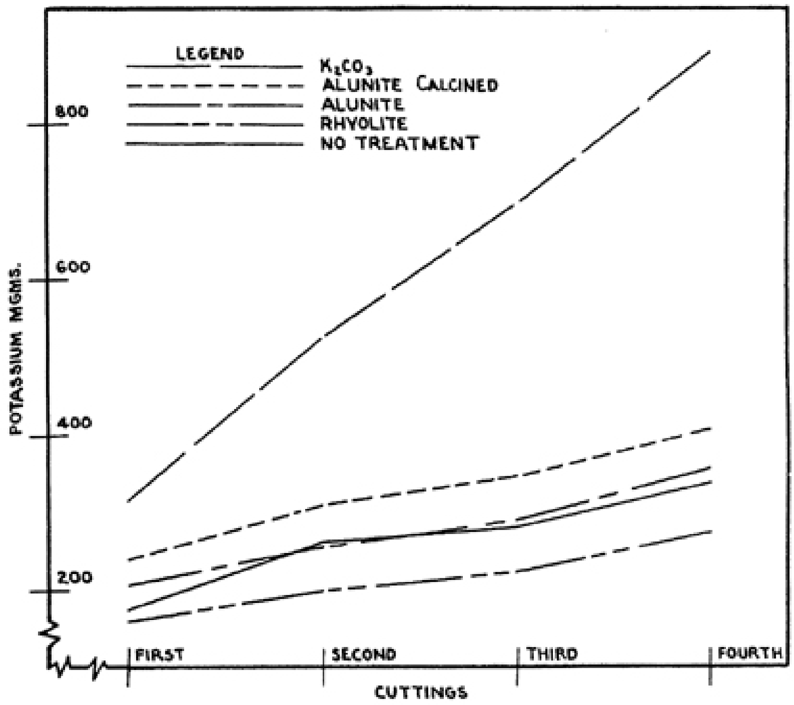

Fig. 1. Potassium harvested in Ladino clover as cumulative totals for the four successive cuttings when the soil was treated with the potassium-bearing minerals: K_2CO_3, alunite calcined, alunite, and rhyolite.

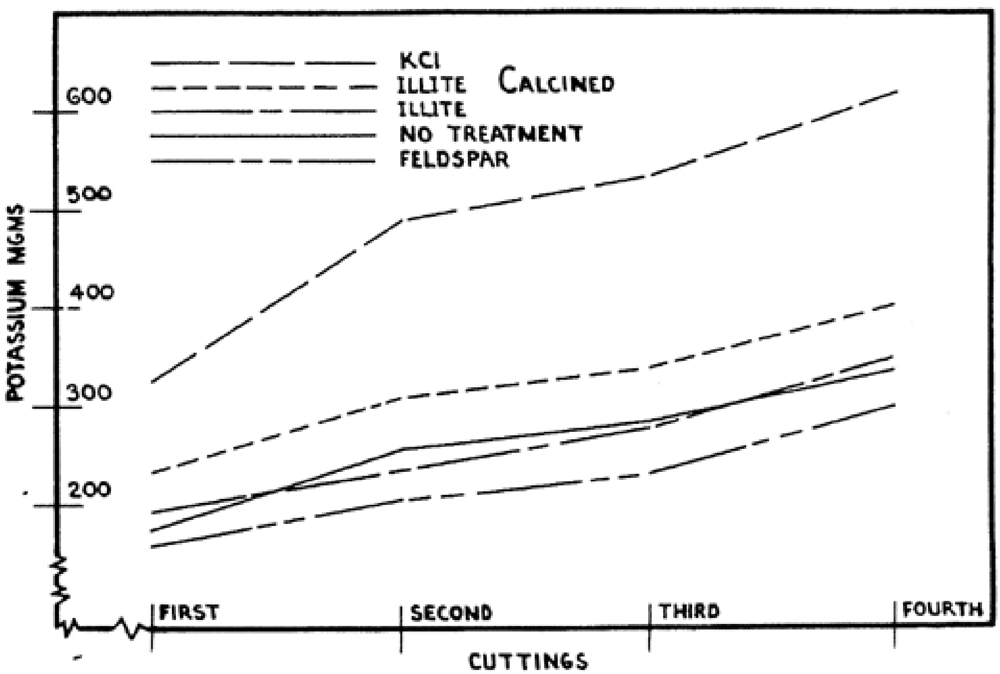

Fig. 2. Potassium harvested in Ladino clover as cumulative totals for the four successive cuttings when the soil was treated with the potassium-bearing minerals: KCl, illite calcined, illite, and feldspar.

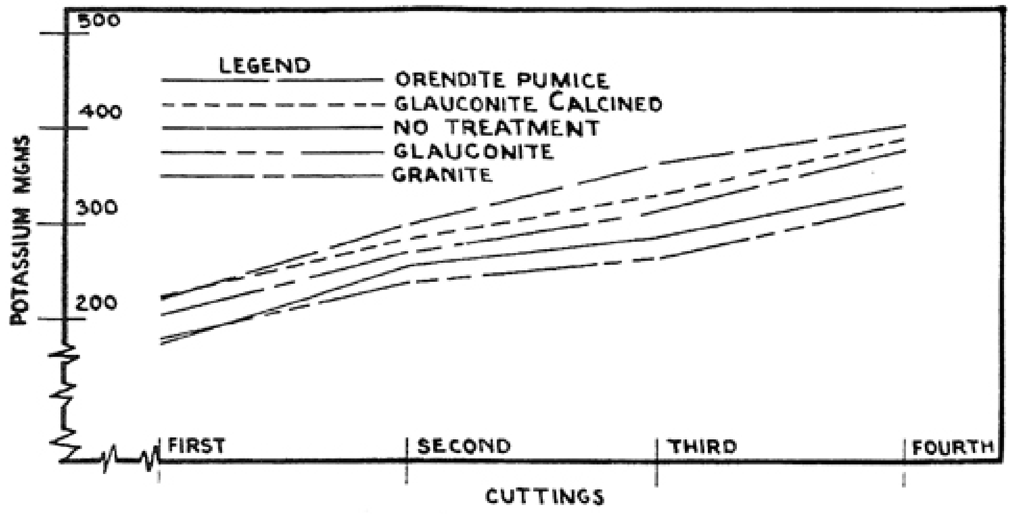

Fig. 3. Potassium harvested in Ladino clover as cumulative totals for the four successive cuttings when the soil was treated with the potassium-bearing minerals: orendite pumice, glauconite calcined, glauconite, and granite.

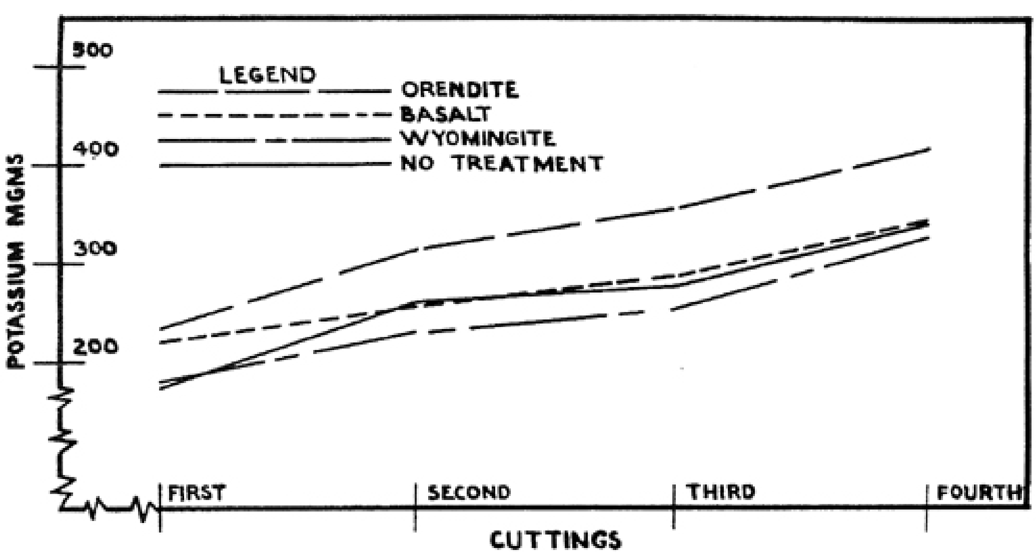

Fig. 4. Potassium harvested in Ladino clover as cumulative totals for the four successive cuttings when the soil was treated with the potassium-bearing minerals: orendite, basalt, and Wyomingite.

may be delivering available potassium for fertilizer service to a growing crop.

The results of this study demonstrated the significance of the reserve minerals already within the soil, and of the natural minerals which might be conveniently applied as helps in keeping up and building up the fertility and productivity of the soil.

Table 5. Yields and Concentrations of Potassium, Calcium, and Magnesium in the Dried Ladino Clover as the Result of Soil Treatments Using Different Potassium-bearing Minerals. (Third Cutting - 56 days of growth)

Treatment	Average yield. Dry Weight gms.	Potassium %	Calcium %	Magnesium %
K_2CO_3	10.7	1.60	1.69	.18
KCl	3.9	1.12	1.80	.16
Orendite Pumice	5.5	1.12	1.69	.24
Orendite	6.8	.63	1.95	.23
Illite (Cal. 400°C.)	4.6	.63	1.72	.24
Alunite (Cal. 400°C.)	5.1	.77	1.87	.16
Glauconite (Cal. 400°C.)	5.7	.83	1.69	.24
Granite	5.8	.73	1.72	.18
Alunite	5.1	.70	1.69	.17
Illite	5.5	.79	1.57	.21
Basalt	5.3	.66	1.53	.17
No Treatment	4.6	.57	1.65	.16
Wyomingite	4.1	.60	1.98	.27
Glauconite	3.9	.73	2.14	.15
Feldspar	4.9	.63	1.53	.17
Rhyolite	4.4	.63	1.84	.24

Table 6. Yields and Concentrations of Potassium, Calcium, and Magnesium in the Dried Ladino Clover as the Result of Soil Treatments Using Different Potassium-bearing Minerals. (Fourth Cutting - 95 days of growth)

Treatment	Average yield. Dry weight gms.	Potassium %	Calcium %	Magnesium %
K_2CO_3	12.1	1.60	2.28	.40
KCl	6.7	1.32	2.74	.40
Orendite Pumice	8.9	1.03	2.40	.35
Orendite	9.8	.62	2.62	.40
Illite (Cal. 400°C.)	8.2	.82	2.25	.40
Alunite (Cal. 400°C.)	6.5	.87	2.48	.33
Glauconite (Cal. 400°C.)	7.2	.90	2.36	.37
Granite	10.3	.62	2.52	.40
Alunite	9.9	.62	2.40	.35
Illite	9.7	.73	2.40	.42
Basalt	10.7	.50	2.36	.40
No Treatment	7.5	.75	2.40	.40
Wyomingite	8.1	.95	2.32	.42
Glauconite	8.8	.67	2.74	.40
Feldspar	9.4	.67	2.54	.35
Rhyolite	8.1	.58	2.32	.35

Table 7. Total Potassium Harvested in Four Successive Cuttings of Ladino Clover as the Result of Soil Treatments Using Different Potash-bearing Minerals. (Total of 258 days of growth)

Treatment	First cutting mgms.	First and second cuttings mgms.	First, second, and third cuttings mgms.	First, second, third, and fourth cuttings mgms.
K_2CO_3	317	527	698	892
KCl	328	489	533	621
Orendite Pumice	221	302	364	456
Orendite	235	314	357	418
Illite (Cal. 400°C.)	233	310	339	406
Alunite (Cal. 400°C.)	241	310	349	406
Glauconite (Cal. 400°C.)	220	287	335	400
Granite	207	272	314	378
Alunite	208	255	291	352
Illite	195	237	280	351
Basalt	222	255	290	343
No Treatment	176	258	284	340
Wyomingite	180	228	253	330
Glauconite	179	237	266	325
Feldspar	159	206	237	300
Rhyolite	162	198	226	273

Table 8. Yields, Chemical Composition, and Total Potassium Harvested in Ladino Clover Grown on Soil Treated With Potash-bearing Minerals Calcined at 700°C.

Treatment	Cutting	Average yield dry weight gms.	Potassium %	Calcium %	Magnesium %	Total potassium harvested with cutting. Mgms.
Alunite	First	7.3	2.28	1.35	.12	167
	Second	8.3	1.60	1.53	.18	300
	Third	8.6	1.68	2.21	.34	445
Glauconite	First	10.0	1.47	1.46	.16	147
	Second	9.4	.94	1.57	.18	236
	Third	12.2	.75	2.10	.34	327
Illite	First	8.6	1.90	1.46	.27	163
	Second	7.6	1.22	1.53	.16	256
	Third	9.7	1.12	2.10	.35	365
Feldspar and Dolomite	First	9.9	1.52	1.46	.28	150
	Second	7.8	1.20	1.57	.30	243
	Third	9.6	.87	2.10	.45	327
K_2CO_3						575
No Treatment						164