TRACING THE MINERAL FROM THE SOIL TO THE PLANT

PART V. EFFECT OF LIME AND PHOSPHORUS ON GUINEA, MERKER, AND PARA-CARIB GRASSES GROWN IN ASSOCIATION WITH TROPICAL KUDZU[1]

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Introduction

The effect of lime and phosphorus on the available calcium, magnesium, manganese, phosphorus, and iron contents of the acid red soil, Fajardo clay, and on the quantities of those elements present, and the yield in various cuttings of Para-Carib grass, was studied from 1943 to 1946 and reported by Bonnet and Riera (1, 2).[3]

This paper presents the data obtained in similar studies, made from 1948 to 1950, with Guinea grass *Panicum maximum* and Merker grass *Pennisetum purpureum* grown alone, and of these grasses and a mixture of Para-grass *Panicum purpurascens* and Carib grass *Eriochloa Polystachya*, grown in association with tropical kudzu *Pueraria phaseoloides*.

Experimental Work

After the final Para-Carib grass cutting was harvested, in the first set of experiments (1, 2), the corresponding thirty-six $\frac{2}{10}$-acre plots were plowed separately. The soil reaction of the previously limed plots of Fajardo clay was found to vary from pH 4.4 to 5.1, and limestone was applied again on March 9, 1948, at rates varying from 0.5 to 4.5 tons per acre to raise the soil reaction to about pH 6.5. The soil reaction of the unlimed plots varied from pH 4.2 to pH 5.0.

A part of some of the plots that had undergone the previous four treatments: Check, calcium, phosphorus, and calcium-phosphorus, was subdivided into five $\frac{1}{100}$-acre plots for the following subtreatments: Guinea grass, Merker grass, Guinea-kudzu, Merker-kudzu, and Para-Carib-kudzu. The experiment covered a total of 120 $\frac{1}{100}$-acre plots consisting of six replications, four fertilizer treatments, and five grass subtreatments.

Seeds of kudzu, scarified with sulfuric acid, 1:1 solution, were planted on May 4, 1948 in the corresponding plots. The respective grasses were planted 3 months later. Each of the grass-kudzu plots had three kudzu and four

[1] This is Part V of the studies hitherto published under the general title: "Tracing the Mineral from the Soil to the Plant to the Animal Blood."

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[3] Numbers in parentheses refer to Literature Cited, p. 154.

grass rows, spaced at 1.5 feet between rows. The grass plots had four rows of grasses, spaced 3 feet apart.
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Phosphorus was applied as a superphosphate to the corresponding plots on July 30, 1948, at the rate of 100 pounds of P_2O_5 to the acre.

The consecutive six grass and grass-kudzu cuttings were harvested around October 13, 1948; January 26, May 24, September 1, and November 30, 1949, and April 19, 1950, respectively. The first and third cuttings each

FIG. 1.—Guinea grass grown in association with kudzu; second cutting, 104 days old.

received an application of 50 pounds NH_3 to the acre, the first as ammonium sulfate and the third as ammonium nitrate.

Figures 1 to 3 show pictures of the various grasses growing in association with tropical kudzu.

PRESENTATION AND DISCUSSION OF THE DATA

YIELDS

The age, season, and yields of dry grass and grass-kudzu per cutting and per treatment are reported in table 1. The crop mean for each of the six cuttings of dry Guinea grass varied from 1.37 to 4.47 tons per acre; for dry Merker grass from 2.82 to 5.66 tons per acre; for the dry Guinea-kudzu

Fig. 2.—Merker grass grown in association with kudzu; second cutting, 104 days old. Observe how the kudzu climbs the stems of the grass.

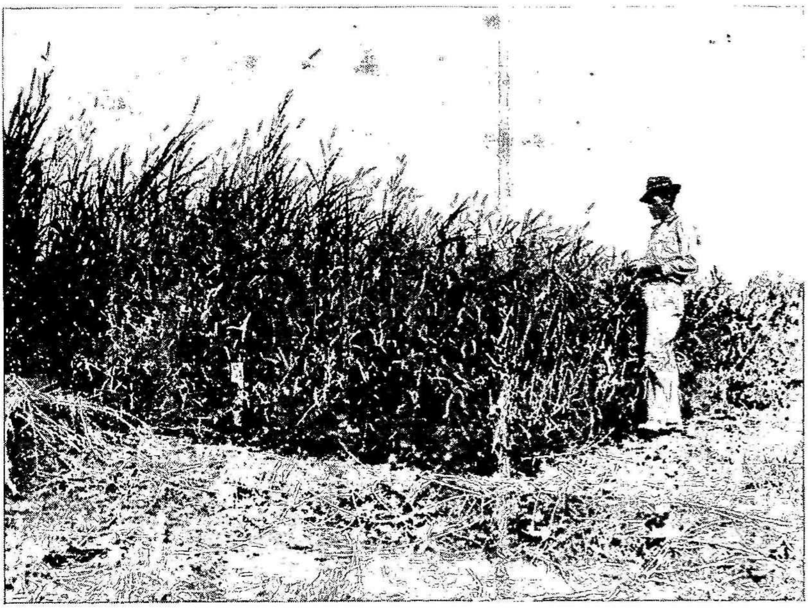

Fig. 3.—Para-Carib grass grown in association with kudzu; second cutting, 104 days old.

TABLE 1.—*Age, season, and yields of 6 cuttings of dry grass and grass-kudzu, in tons per acre, as related to treatments*

Cutting	Season	Crop age (days)	Symbol[1]	Check	Ca	P	CaP	Crop-mean
1	Fall	70[2]	G	3.00	2.67	2.38	2.87	2.73
			M	3.13	3.67	3.13	3.80	3.43
			GK	3.47	3.53	3.20	3.49	3.43
			MK	3.68	4.28	3.36	4.53	3.97
			PK	3.08	3.44	2.88	3.54	3.24
			Treatment mean	3.26	3.52	2.99	3.65	3.36
2	Winter	104	G	1.82	1.97	1.69	2.00	1.87
			M	2.43	3.28	2.52	3.58	2.95
			GK	2.78	3.15	3.12	3.42	3.12
			MK	3.75	5.30	3.29	6.26	4.65
			PK	2.45	3.03	3.03	3.54	3.01
			Treatment mean	2.64	3.35	2.73	3.76	3.12
3	Spring	119	G	2.96	3.27	2.52	3.07	2.96
			M	2.61	3.85	3.02	4.04	3.38
			GK	4.07	4.21	4.30	4.02	4.15
			MK	4.83	5.09	4.46	4.86	5.04
			PK	2.91	2.47	3.18	3.43	3.00
			Treatment mean	3.48	3.78	3.50	4.06	3.71
4	Summer	99	G	4.23	4.84	4.16	4.66	4.47
			M	4.45	6.57	5.03	6.60	5.66
			GK	5.07	5.47	5.64	5.34	5.38
			MK	5.54	6.91	5.81	7.35	6.40
			PK	3.76	3.82	4.04	4.17	3.95
			Treatment mean	4.61	5.52	4.94	5.61	5.17
5	Fall	62	G	2.23	2.64	1.78	2.14	2.20
			M	3.09	3.53	2.54	3.68	3.21
			GK	2.62	3.05	2.62	2.85	2.78
			MK	3.79	4.38	3.51	4.30	4.00
			PK	2.21	2.31	2.10	2.46	2.27
			Treatment mean	2.79	3.22	2.51	3.09	2.90
6	Winter	148	G	1.54	1.20	1.19	1.53	1.37
			M	2.42	3.48	2.20	3.19	2.82
			GK	2.44	2.09	2.28	2.38	2.30
			MK	3.15	4.04	3.05	4.07	3.58
			PK	2.96	2.36	2.50	2.77	2.65
			Treatment mean	2.50	2.63	2.24	2.79	2.54

[1] G—Guinea grass; M—Merker grass; GK—Guinea-kudzu; MK—Merker-kudzu; PK—Para-Carib-kudzu.
[2] Age of kudzu was 160 days in first cutting.

from 2.30 to 5.38 tons per acre; for the dry Merker-kudzu from 3.58 to 6.40 tons per acre; and for the dry Para-Carib-kudzu from 2.27 to 3.95 tons per acre. The highest yields were obtained during the summer.

The growth period for the six cuttings was 602 days, not counting the 90-day period for the kudzu that was planted before the first crop. The dry yields per acre per year of the respective crops were 9.46 tons of Guinea grass, 13.01 tons of Merker grass, 12.83 tons of Guinea-kudzu, 16.76 tons of Merker-kudzu, and 10.99 tons of Para-Carib-kudzu. The green yields per acre per year were about four times the values reported for the dry yields. The Merker-kudzu association gave the highest yield, equivalent to about 67 tons, green weight, per acre per year. The mean moisture contents

TABLE 2.—*Mean dry yields, in tons per acre, under all treatments, of each of the 6 grass and grass-kudzu cuttings, and test of significance*

Cutting No.	Guinea	Merker	Guinea-kudzu	Merker-kudzu	Para Carib-kudzu	L. S. D. at—	
						1-percent point	5-percent point
1	2.73	3.43	3.47	3.97	3.24	0.45	0.34
2	1.87	2.95	3.12	4.65	3.01	.58	.44
3	2.96	3.38	4.15	5.04	3.00	.61	.46
4	4.47	5.66	5.36	6.41	3.99	.71	.53
5	2.20	3.21	2.85	3.95	2.27	.60	.45
6	1.45	3.06	2.25	3.81	2.58	.61	.46

TABLE 3.—*Mean dry yields, in tons per acre, for each treatment of all the respective grass and grass-kudzu cuttings, and test of significance*

Cutting No.	Check	Ca	P	CaP	L. S. D. at—	
					1-percent point	5-percent point
1	3.27	3.52	2.99	3.65	0.32	0.23
2	2.64	3.35	2.73	3.76	.98	.71
3	3.48	3.78	3.50	4.06	1.15	.84
4	4.61	5.52	4.94	5.64	.82	.60
5	2.76	3.19	2.58	3.06	.65	.47
6	2.59	2.76	2.26	2.89	.65	.45

of the green grasses varied from 67.2 to 71.3 percent and of the kudzu from 73.6 to 74.9 percent.

The mean dry yields, in tons per acre, for all treatments of each of the 6 grass and grass-kudzu cuttings and tests of significance are reported in table 2, and per treatment of all the respective grass and grass-kudzu cuttings in table 3.

There were highly significant differences between the mean dry yields of the grasses. The Merker grass-kudzu association gave the highest yields in all the cuttings. There was a highly significant response to treatments for the fourth cutting, a significant response for the second cutting, and no response for the first, third, fifth, and sixth cuttings. Although in general there were no significant differences between yields attributable to treatments for the first, fifth, and sixth cuttings, the application of calcium significantly increased the crop yields. The significant responses obtained in the second and fourth cuttings are attributed to the effect of calcium, not phosphorus. Throughout the whole experiment the increase attributable to the application of lime to the Merker-kudzu was from 24.74 to 30.00 tons of dry forage per acre, or 2.77 tons of dry forage (table 1) per acre per year, equivalent to 9.23 tons of green forage containing 70 per cent of water. Assuming that a 1,000-pound cow ate 70 pounds of that green forage per day, the increase of 9.23 tons of green forage from lime application was equivalent to a carrying capacity of 264 cow-days per acre.

TABLE 4.—*Analysis of variance for the combined 5 cuttings of the grass and grass-kudzu associations calculated from dry yields in terms of hundredweights per acre*

Source of variation	D. F.	S. S.	Variance	*F*
Total	119	47,145.8		
Blocks	5	2,512.7		
Treatments	3	4,638.9	1,546.3	4.83
Error (a) blocks and fertilizer	15	4,797.4	319.8	
Grasses[1]	4	22,033.0	5,508.2	44.28
Treatments and grasses	12	3,215.3	267.9	2.15
Error (b)	80	9,948.5	124.4	
P_2O_5	1	92.3	92.3	
Ca	1	4,473.7	4,473.7	13.99
Ca + P_2O_5	1	72.0	72.0	

[1] Includes kudzu-grasses.

The statistical analysis for the combined five cuttings is reported in table 4; the sixth cutting was discarded because of too many missing plots. There was a highly significant response due to grasses and a significant response due to treatments and to the interaction between treatments and grasses (table 4). Among the treatments, there was a highly significant response only for calcium. The grasses responded differently in yield to the calcium; the Merker and Merker-kudzu responded highly significantly but the Guinea, Guinea-kudzu, and Para-Carib-kudzu did not respond (table 5). None responded to phosphorus.

The yields of kudzu and of the grasses grown in association with it are given separately. The dry-yield data, in tons per acre per treatment, for each of the six cuttings, are reported separately for the kudzu and grasses in table 6. The mean dry yield of kudzu per cutting varied from 1.02 to

TABLE 5.—*Mean dry yields, in tons per acre, of the 5 combined cuttings of the grass and the grass-kudzu associations, as related to treatments*

Treatment	Mean dry yield of[1]—				
	Guinea	Merker	Guinea-kuzdzu	Merker-kudzu	Para-Carib-kudzu
Check	2.85	3.06	3.60	4.30	2.88
Calcium	3.08	4.19	3.88	5.19	3.01
Phosphorus	2.51	3.25	3.83	4.09	3.06
Calcium-phosphorus	2.95	4.34	3.81	5.63	3.46

[1] Least significant differences between the means of two grasses with the same or different treatments are 0.64 for the 1-percent point and 0.85 for the 5-percent point.

TABLE 6.—*Separate and total dry yields, in tons per acre, of 6 cuttings of Guinea, Merker, and Para-Carib grasses grown in association with kudzu, as related to treatments*

Cutting No.	Treatment	Yield of grasses indicated[1]								
		G	K	GK	M	K	MK	P	K	PK
1	Check	0.80	2.67	3.47	1.36	2.32	3.68	1.37	1.71	3.08
	Ca	1.29	2.24	3.53	1.74	2.54	4.28	2.10	1.34	3.44
	P	1.40	1.80	3.20	1.25	2.11	3.36	1.70	1.18	2.88
	CaP	1.40	2.09	3.49	2.30	2.23	4.53	2.18	1.36	3.54
2	Check	1.71	1.07	2.78	2.35	1.40	3.75	1.59	.86	2.45
	Ca	2.21	.94	3.15	4.45	.85	5.30	2.50	.53	3.03
	P	2.25	.87	3.12	2.61	.68	3.29	2.48	.55	3.03
	CaP	2.57	.85	3.42	5.40	.86	6.26	2.96	.58	3.54
3	Check	2.42	1.65	4.07	3.00	1.83	4.83	1.92	.99	2.91
	Ca	2.56	1.65	4.21	3.47	1.62	5.09	1.65	.82	2.47
	P	3.04	1.26	4.30	3.00	1.46	4.46	2.10	1.08	3.18
	CaP	2.74	1.28	4.02	3.77	1.09	4.86	2.31	1.12	3.43
4	Check	3.86	1.21	5.07	3.45	2.09	5.54	2.56	1.20	3.76
	Ca	3.45	2.02	5.47	5.00	1.91	6.91	2.40	1.42	3.82
	P	4.45	1.19	5.64	4.23	1.58	5.81	2.53	1.51	4.04
	CaP	3.84	1.50	5.34	5.55	1.80	7.35	3.11	1.06	4.17
5	Check	1.70	.92	2.62	2.33	1.46	3.79	1.28	.93	2.21
	Ca	2.02	1.03	3.05	3.13	1.25	4.38	1.60	.71	2.31
	P	1.67	.95	2.62	2.24	1.27	3.51	1.44	.66	2.10
	CaP	2.00	.85	2.85	2.84	1.46	4.30	1.81	.65	2.46
6	Check	1.46	.98	2.44	1.96	1.19	3.15	1.83	1.13	2.96
	Ca	1.21	.88	2.09	3.09	.95	4.04	1.25	1.11	2.36
	P	1.44	.84	2.28	1.87	1.18	3.05	1.47	1.03	2.50
	CaP	1.18	1.20	2.38	2.59	1.48	4.07	1.83	.94	2.77
Mean		2.19	1.33	3.53	3.04	1.53	4.57	2.00	1.02	3.02

[1] G—Guinea grass; M—Merker grass; GK—Guinea-kudzu; MK—Merker-kudzu; PK—Para-Carib-kudzu.

TABLE 9.—*Calcium, magnesium, manganese, phosphorus, and iron (parts per million) contents of the first cutting of the grasses and the kudzu-grass associations (dry basis) grown under different treatments*

Crop	Treatment	Calcium	Magnesium	Manganese	Phosphorus	Iron
Guinea grass	Check	4,865	2,799	263	1,465	339
	Ca	7,662	4,180	213	1,063	293
	P	5,032	2,787	330	1,377	294
	CaP	8,494	3,614	171	1,321	204
Merker grass	Check	3,008	1,931	116	1,463	898
	Ca	4,762	2,237	92	2,144	325
	P	2,967	2,083	158	1,038	647
	CaP	4,120	2,008	107	1,587	209
Guinea grass	Check	4,672	3,845	289	1,800	572
	Ca	11,251	3,416	209	1,446	233
	P	5,430	3,025	334	1,507	460
	CaP	12,377	3,870	171	1,719	504
Kudzu	Check	7,251	4,930	381	1,935	852
	Ca	11,550	4,168	188	1,737	686
	P	9,449	4,378	343	1,884	1,029
	CaP	12,279	3,913	155	1,838	762
Merker grass	Check	6,915	2,217	142	1,937	287
	Ca	5,160	2,221	102	2,836	284
	P	3,333	2,332	168	2,095	478
	CaP	4,436	2,314	102	2,654	480
Kudzu	Check	7,751	4,552	298	2,013	466
	Ca	7,658	4,307	151	1,568	771
	P	7,554	5,397	362	1,915	1,415
	CaP	10,929	4,140	217	2,154	1,263
Para-Carib grass	Check	3,323	1,981	196	2,128	700
	Ca	5,476	2,126	85	1,906	213
	P	3,731	2,313	147	1,870	571
	CaP	5,010	2,173	75	1,803	353
Kudzu	Check	5,768	3,852	328	2,316	1,463
	Ca	11,480	3,519	161	1,955	999
	P	7,587	5,002	337	2,365	1,959
	CaP	11,554	4,279	147	1,926	1,827

four treatments. The statistical interpretations of the data are given in tables 10 and 11.

There was a highly significant difference in the contents of calcium, magnesium, manganese, phosphorus, and iron for each of the grasses, grass-kudzu associations, and kudzu.

Guinea grass absorbed more calcium, magnesium and manganese than Merker grass. Guinea grass grown in association with kudzu absorbed more calcium, magnesium and manganese than Merker and Para-Carib grasses grown in association with kudzu, (table 10).

TABLE 10.—*Mean calcium, magnesium, manganese, phosphorus, and iron contents (parts per million) of the first cuttings of the grasses and grass-kudzu associations and least significant differences, as affected by treatments*

Grasses[1] and associations	Ca × 100	Mg × 100	Mn × 10	P × 100	Fe × 10
G	65	34	24	13	28
M	37	20	12	16	52
G_K	84	35	25	16	44
K_G	101	43	27	18	83
M_K	50	22	13	24	38
K_M	85	46	26	19	98
P_K	44	22	13	19	46
K_P	91	41	24	22	156
L.S.D. at 5-percent level	23	6	6	4	33
L.S.D. at 1-percent level	31	8	8	6	45

[1] G—Guinea grass; M—Merker grass; G_K—Guinea with Kudzu; M_K—Merker with kudzu; P_K—Para-Carib with kudzu; K_G—kudzu with Guinea; K_M—kudzu with Merker; K_P—kudzu with Para-Carib.

TABLE 11.—*Mean calcium, magnesium, manganese, phosphorus, and iron, contents (parts per million) of the first cuttings of the grasses and grass-kudzu associations and least significant differences, as affected by treatments*

Treatment	Ca × 100	Mg × 100	Mn × 10	P × 100	Fe × 10
Check	54	32	25	19	70
Ca	81	33	15	18	47
P	56	34	27	18	86
CaP	86	33	14	18	70
L.S.D. at the 5-percent level	17	6	4	4	23
L.S.D. at the 1-percent level	23	8	5	6	31

There was no difference in the amount of phosphorus absorbed by Guinea and Merker grasses when grown alone but Merker grass absorbed more phosphorus than Guinea and Para-Carib grasses when the three grasses grew in association with kudzu.

There was no difference in the amount of iron absorbed by the grasses. Kudzu absorbed more calcium, magnesium, and iron than the three grasses and more manganese than Merker and Para-Carib grasses; but as much as Guinea grass.

There were highly significant differences attributable to treatments in the calcium and manganese contents of the grasses and grass-kudzu associations, significant differences in the iron content, and no significant difference in the magnesium and phosphorus contents. Bonnet and Riera (1, 2) found previously with Para-Carib grass that: "When lime or lime and phosphorus were applied, there was a highly significant increase of calcium and phosphorus and a highly significant decrease of manganese in the grass but the iron and magnesium contents were not affected. When phosphorus was applied without lime, there was a significant increase of phosphorus in the grass, but no significant change in the other minerals. There was also a significant difference between the phosphorus content of the grass that received phosphorus and that with calcium and phosphorus. The latter had the higher content."

The addition of lime or lime and phosphorus increased the calcium content and decreased the manganese content of the grasses and grass-kudzu associations (table 11). The addition of lime decreased the iron content. There was no difference in the magnesium and phosphorus contents. The addition of phosphorus with the lime increased the iron content but there was no change when the phosphorus was added alone. There was no significant interaction between lime and phosphorus to cause changes in the iron content.

Summary

The effect of lime and phosphorus added to an acid soil of Puerto Rico was studied in relation to the yields and mineral contents of Guinea and Merker grasses, and of these grasses and Para-Carib grown in association with a legume, tropical kudzu, and as well as of kudzu itself. The results were as follows:

1. There was a highly significant response of the grasses to the lime application but the kudzu did not respond. The Merker grass-kudzu association produced the highest yields.

2. There was no significant response of either the grasses or kudzu to the addition of phosphorus.

3. The increase of green Merker grass-kudzu forage from lime application was equivalent to a carrying capacity of 264 cow-days per acre.

4. The protein content of the grasses grown in association with the kudzu was increased.

5. There was a highly significant difference in the contents of calcium,

magnesium, manganese, phosphorus, and iron for each of the grasses, grass-kudzu associations, and kudzu.

6. Guinea grass absorbed more calcium, magnesium, and manganese than Merker grass. Guinea grass grown in association with kudzu absorbed more calcium, magnesium, and manganese than Merker and Para-Carib grasses grown in association with kudzu.

7. There was no difference in the amount of phosphorus absorbed by Guinea and Merker grasses when grown alone, but Merker grass absorbed more phosphorus than Guinea and Para-Carib grasses when the three grasses grew in association with kudzu.

8. There was no difference between the amounts of iron absorbed by the grasses.

9. Kudzu absorbed more calcium, magnesium, and iron than the three grasses and more manganese than Merker and Para-Carib grasses, but only as much as Guinea grass.

10. There were highly significant differences resulting from treatments in the calcium and manganese contents of the grasses and grass-kudzu associations, significant differences in the iron content, and no significant difference in the magnesium and phosphorus contents.

11. The addition of lime or lime and phosphorus increased the calcium content and decreased the manganese content of the grasses and grass-kudzu associations. The addition of lime decreased the iron content. There was no difference in the magnesium and phosphorus contents. The use of phosphorus with the lime increased the iron content, but there was no change when the phosphorus was added alone.

Resumen

Se estudiaron los efectos de la adición de cal y fósforo a un suelo ácido de Puerto Rico, en lo que concierne a los rendimientos y contenido de minerales de las yerbas Guinea y Merker, de la combinación de éstas y la Pará-Caribe, desarrolladas en asociación con la leguminosa Kudzú tropical, como también el Kudzú solo. Los resultados fueron los siguientes:

1. Las yerbas respondieron en forma altamente significativa a las aplicaciones de cal. No fué así en lo que respecta al Kudzú. La yerba Merker, al crecer asociada con el Kudzú, produjo los rendimientos mayores.

2. Ni las yerbas, ni el Kudzú, respondieron significativamente a las aplicaciones de fósforo.

3. El aumento registrado en la cantidad del forraje, en la asociación de la yerba Merker y el Kudzú, cuando se aplicó la cal, equivalió a una capacidad de sostenimiento de 264 vacasdías por acre.

4. Se aumentó el contenido de proteína en las yerbas que crecieron en asociación con el Kudzú.

5. Hubo diferencias altamente significativas entre los contenidos de calcio, magnesio, fósforo y hierro en cada una de las yerbas, en las asociaciones de yerba y Kudzú y en el Kudzú solo.

6. La yerba Guinea absorbió más calcio, magnesio y manganeso que la yerba Merker. La Guinea, en asociación con el Kudzú absorbió más calcio, magnesio y manganeso que la Merker y la Pará-Caribe, cuando crecieron asociadas con el Kudzú.

7. No hubo diferencia alguna en la cantidad de fósforo que absorbieron las yerbas Guinea y Merker cuando crecieron solas, pero la Merker absorbió más fósforo que la Guinea y la Pará-Caribe, cuando las tres yerbas crecieron en asociación con el Kudzú.

8. No hubo diferencia alguna en la cantidad de hierro que absorbieron las yerbas.

9. El Kudzú absorbió más calcio, magnesio y hierro que las tres yerbas y más manganeso que las Merker y Pará-Caribe, pero sólo la misma cantidad que la Guinea.

10. Hubo una diferencia altamente significativa, como resultado de los tratamientos, en el contenido de calcio y manganeso de las yerbas solas y en la asociación de Kudzú y las yerbas; fué significativa en el contenido de hierro y nula en cuanto a magnesio y fósforo.

11. La adición de cal, o de cal y fósforo, aumentó el contenido de cal y disminuyó el de manganeso en las yerbas solas y en las asociaciones del Kudzú y las yerbas. Cuando se añadió cal, disminuyó el contenido de hierro, pero no hubo diferencia en el contenido de magnesio y fósforo. Cuando se mezclaron y añadieron el fósforo y la cal, aumentó el contenido de hierro, pero no hubo cambio alguno cuando se añadió el fósforo solo.

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