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Potassium competition in grass-legume associations as a function of root cation exchange capacity.

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Potassium Competition in Grass-Legume Associations As a Function of Root Cation Exchange Capacity

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POTASSIUM COMPETITION IN GRASS-LEGUME ASSOCIATIONS

AS A FUNCTION OF ROOT CATION EXCHANGE CAPACITY

by

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INTRODUCTION

It has frequently been observed that in grass-legume pasture mixtures, the legumes in the mixture become unproductive or die out entirely after a few years. In order to investigate this problem, Blaser and Brady (2) set up a field experiment on an established pasture containing 5 per cent Ladino clover, 60 per cent timothy, 20 per cent Kentucky bluegrass, 10 per cent quack grass, and 5 per cent weeds growing on a soil containing 41 pounds of exchangeable K_2O per acre. Results of their work indicated that there was strong competition for K among the species. Yields and analyses showed that the grasses were much more effective in the removal of K from the soil than was the clover.

Efforts are now being directed toward an explanation of the competition between plant species for cations on the basis of the cation exchange capacity of the plant roots. That plant roots possess the property of cation exchange has been demonstrated by De Veux (3) and by Williams and Coleman (19).

According to Wiklander (18) . . . "the adsorption of divalent ions in relation to that of monovalent ones is favoured by a high exchange capacity of the adsorber, which is caused by the interrelation of the ion valency and the activity of the ions in the absorbed position and in the intermicellar solution". In other words, a colloid with high cation exchange capacity adsorbs relatively more divalent than monovalent cations, and, conversely a colloid with low cation exchange capacity adsorbs relatively more monovalent than divalent cations.

Investigations by Mattson (10, 11) have led him to theorize that, other things being equal, plants should be supplied relatively better with divalent than with monovalent cations from a soil having a low cation exchange capacity; and plants should be supplied relatively better with monovalent than with divalent cations from a soil having a high cation exchange capacity. According to Mattson, this holds true only in dilute soil solutions. As the soil solution becomes more concentrated, there are decreasing differences in the mono-vs. divalent cation supplying power of the two soils. Mattson (10) further states . . . "it is only when nearly all of the cations exist in combination with the soil and plant acidoids that a definite valence effect is to be expected. It is only when the plants have to compete with the soil for ions by exchange that the Donnan distribution will be reflected in the composition of the plants". Mattson's theory on the release of cations from soils of different cation exchange capacity has been substantiated in the laboratory (8, 9) and in the field (1, 6, 13).

Mattson (10) suggested that if the uptake of cations by the same plant specie from soils of different cation exchange capacity is according to the Donnan theory of membrane equilibria, then the uptake of cations by different plant species from the same soil might be regulated by the cation exchange capacity of the plant root colloids. A number of investigators (4, 7, 12, 16) have shown that plant species differ greatly in their feeding power for K and Ca.

Drake et al (5) made a study of the order and magnitude of the cation exchange capacity of the roots of a number of agricultural plants. They found that, in general, the cation exchange capacity of the roots of dicotyledenous plants was higher than that of monocotyledonous plants. In theory, then, in a grass-legume mixture growing on a soil having a low level of exchangeable K, the grasses, because of the low cation exchange capacity of their root colloids, will absorb relatively more K than will the legumes (high root cation exchange capacity). Legumes may absorb large amounts of Ca but may be unable to compete successfully with the grasses for K. Does the associated grass compete with legumes for K to the extent that legume yields and longevity of stands are seriously reduced?

In order to determine to what extent this theory of differential cation uptake by plants of different root cation exchange capacity can be used to explain the disappearance of legumes from pasture mixtures, and to what extent cation exchange capacities of legume and grass roots can be used as a measure of K compatibility, an experiment was set up with the following objectives in mind:

1. To measure relative differences in K uptake by separate plantings of Ladino clover and grass species with roots of different cation exchange capacities;

2. To determine the difference in K competition between grass species when grown in association with a legume;

3. To demonstrate that the more nearly equal the cation exchange capacity of the roots of the grass and legume, the more compatible will be the mixture for K.

4. To study the relative difference in K competition between grass and Ladino clover associations at different levels of K.

EXPERIMENTAL PROCEDURE

The plant species used in this greenhouse pot experiment were Ladino clover, smooth brome grass, Kentucky bluegrass, and bentgrass having root cation exchange capacities of 43.4, 24.4, 21.6, and 16.3 me/100 gms.* respectively (5).

The soil used was that from the A horizon of a Merrimac fine sandy loam which had been out of cultivation for over twenty years. Some chemical characteristics of this soil are shown in table 1.

TABLE 1

Characteristics of Merrimac Fine Sandy Loam.

pH	Per cent organic matter	Exchangeable cations me/100 gms soil		
		Ca	K	Na
6.1	2.19	2.78	0.113	0.157

Exchangeable cations were extracted by the electrodialysis method (15), and organic matter was determined by the Walkley-Black method (14). A petrographic analysis analysis of the soil** revealed that the mineral fraction was fairly abundant in albite (Na-feldspar) and to a lesser extent in K-feldspar and K bearing hydrous mica.

In November, cuttings from stolans of the plant species were transplanted from sand flats to glazed porcelain pots (without drains) containing 3000 grams of air dry soil. The plants were grown in two groups. In Group I, the species were grown separately, in Group II, Ladino clover was grown in combination with each of the grasses. The treatments

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* Milliequivalents per 100 grams of dry roots

**Courtesy Dr. W. A. Light, Geology Dept., University of Massachusetts, Amherst.

used in this experiment are shown in Table 2.

TABLE 2

Potassium added to Merrimac fine sandy loam containing 100 pounds of exchangeable K_2O/acre.

Group I	Group II
1. 0	1. 0
2. 120 K_2O initially	2. 60 K_2O* initially
3. 300 K_2O initially	3. 0 initially plus 60 K_2O after 1st cutting
	4. 60 K_2O initially plus 60 K_2O after 1st cutting
	5. 120 K_2O initially

* 60 pounds K_2O = 144 mg. KCl/pot.

All pots received superphosphate (20% P_2O_5) at the rate of 1 ton per acre, dolomitic limestone (30% CaO, 20% MgO) at the rate of 3 tons per acre, and nitrogen at the rate of 600 pounds of NH_4NO_3 (33 1/3% N) per acre. Boron, as $Na_2 B_4O_7$, at the rate of 20 pounds per acre and additional nitrogen at the rate of 100 pounds NH_4NO_3 per acre were supplied once during the experiment. A randomized block design with five replicates of each treatment was used. Demineralized water was used throughout the experiment, and the water content of the soil was maintained at approximately 60 per cent of the water holding capacity of the soil. Harvest dates were January 21, March 2, and April 5. The harvested clippings were dried at 70° C. The samples were wet ashed and the K and Ca contents were determined by a Perkin-Elmer flame photometer (17).

RESULTS

Group I

In the first cutting, increasing the soil K from exchangeable K to exchangeable K plus 120 K_2O resulted in a growth response for all species (table 4). However, smooth brome grass was the only species which showed visible growth response to the first increment of K before the first cutting. Increasing the soil K from exchangeable K plus 120 K_2O to exchangeable K plus 300 K_2O produced no further growth response (table 3). All species increased in K content as the soil K was increased (table 3). There was considerable variation within replicates due to the difficulty encountered in establishing stands.

Yields in the second cutting showed that for all species there was a growth response when soil K was increased from exchangeable K to exchangeable K plus 120 K_2O (table 3). As in the first cutting, smooth brome grass was the only species that made noticeable response to the application of 120 pounds K_2O. Exchangeable K + 300 K_2O did not produce further growth increases (table 3). The per cent K increased in all species as the soil K was increased (table 3).

Following the second cutting, observed recovery of Ladino clover and bent grass at the exchangeable K level was noticeably poorer than when potash was added to the soil. Yields in the third cutting showed that Ladino clover and bentgrass made marked growth responses at exchangeable K plus 120 K_2O, but, although Ladino clover plants at 120 pounds added K_2O were lighter in color than at 300 pounds added K_2O, no additional growth increase was produced at the higher K level (table 3). Kentucky bluegrass made a slight increase in yields at exchangeable K plus 120 K_2O, but showed no further growth response at exchangeable K plus 300 K_2O (table 3). Growth was poor in two replicates of Kentucky blue grass at the 300 pound K_2O application which accounts for the apparent decrease in yield at this level. All species increased in per cent K as the soil K was increased (table 3). After the second cutting, smooth brome grass made poor recovery, several plants died, and yield results were erratic.

Figure 1 shows the total uptake of K by the different plant species for three cuttings at different levels of soil K. Total K uptake by Ladino clover, smooth brome grass, Kentucky blue grass, and bentgrass at each of the three levels of K agrees well with the respective root cation exchange capacity. Smooth brome grass removed less K than did Ladino clover; however, yields of smooth brome grass were abnormally low. Kentucky blue grass removed less K at 300 pounds added K_2O than did Ladino clover because of abnormally poor growth in two replicates.

Results from Group I are shown in tables 3, 4, and 5 and figures 1 and 2.

TABLE 3

Yield and potassium content of separate plantings of Ladino clover, bentgrass, Kentucky bluegrass, and smooth brome grass.*

Exchangeable K	First Cutting dry wt. grams	% K	Mgm. K	Second Cutting dry wt. grams	% K	Mgm. K	Third Cutting dry wt. grams	% K	Mgm. K
Ladino clover	1.728	1.40	23.24	2.207	0.74	16.36	2.301	0.60	13.88
bent grass	4.155	1.96	80.14	3.895	0.98	37.36	2.741	0.81	21.33
Ky. bluegrass	2.310	2.08	47.95	2.695	0.92	25.36	2.934	0.89	26.11
smooth brome grass	1.743	1.79	30.66	0.568	1.12	5.41	0.158	1.01	1.60
Exchangeable K plus 120 K_2O									
Ladino clover	2.364	2.31	51.57	2.672	1.33	35.31	3.496	1.10	38.46
bentgrass	5.234	1.79	91.55	4.228	1.41	58.87	3.660	1.14	41.72
Ky blue grass	2.691	3.06	80.23	3.043	1.67	50.60	3.554	1.37	48.69
smooth brome grass	3.114	2.80	87.24	1.122	1.76	20.26	0.388	1.50	5.82
Exchangeable K plus 300 K_2O									
Ladino clover	1.951	3.05	59.20	2.746	2.33	61.54	3.686	1.96	72.25
bentgrass	5.244	2.28	113.56	4.469	2.47	110.93	3.768	1.98	74.61
Ky. blue grass	2.516	3.31	78.42	2.102	2.17	46.60	2.396	2.22	53.19
smooth brome grass	2.971	3.39	95.69	0.964	2.66	23.05	0.326	2.74	8.93

*Average of five replicates

TABLE 4

Total yield and K uptake by separate plantings of Ladino clover, bent grass, Kentucky blue grass, and smooth brome grass at different K levels.*

	Exchangeable K dry wt. grams	Exchangeable K Mgm K	Exch. K + 120 K_2O dry wt. grams	Exch. K + 120 K_2O Mgm K	Exch. K + 300 K_2O dry wt. grams	Exch. K + 300 K_2O Mgm K
Ladino clover	6.236	53.48	8.532	125.34	8.383	192.99
bentgrass	10.791	138.83	13.122	192.14	13.481	299.10
Kentucky blue grass	7.939	99.42	9,288	179.52	7.014	178.21
smooth brome grass	2.469	37.67	4.624	113.32	4.261	127.67

*Average of five replicates for 3 cuttings

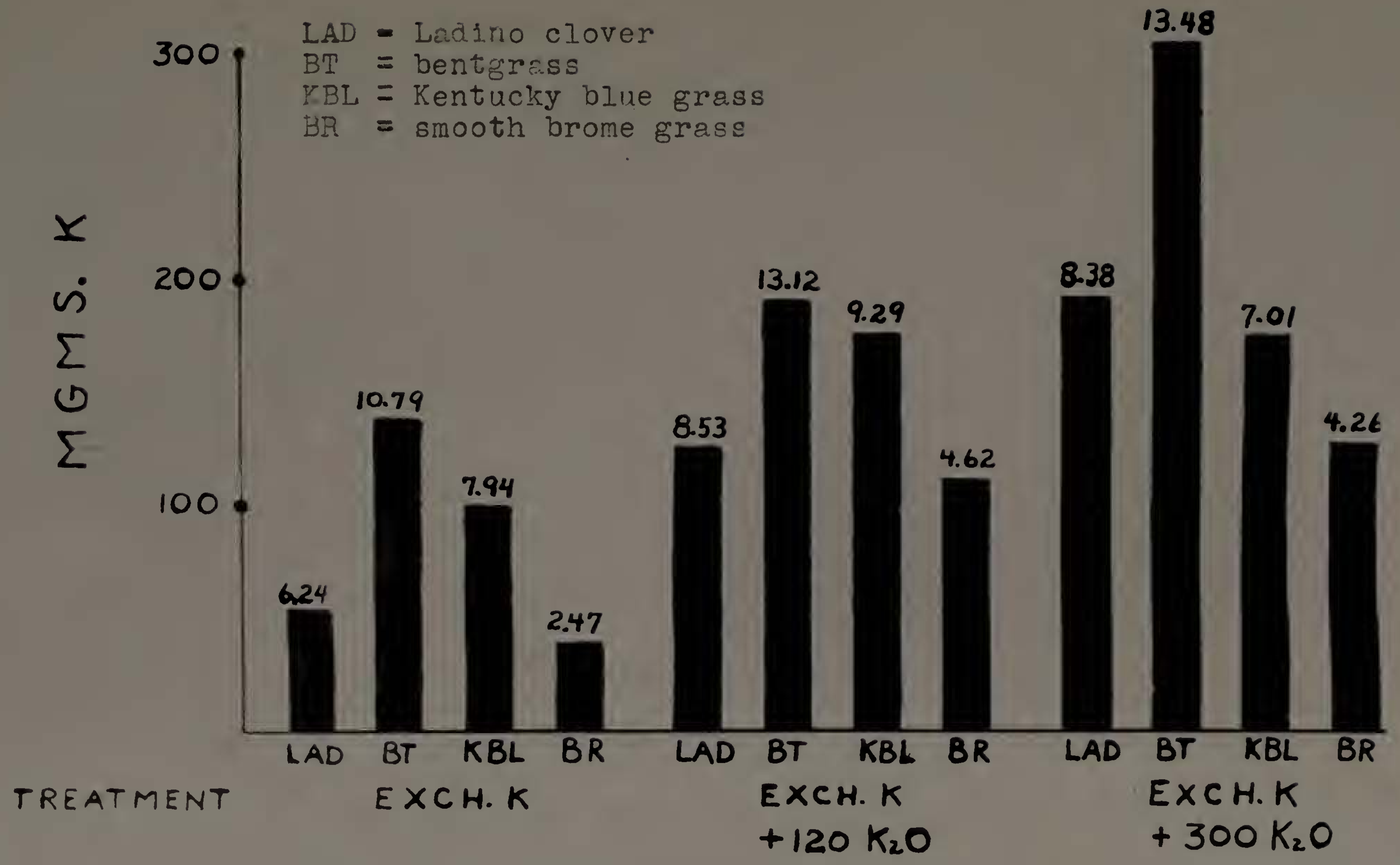

Figure 1. Total yield and K uptake by separate plantings of Ladino clover, bentgrass, Kentucky blue grass, and smooth brome grass at different K levels. Figures at the end of the bars represent total dry matter production in grams for three cuttings.

TABLE 5

Relative uptake of K at different K levels by bentgrass, Kentucky tucky blue grass, smooth brome grass and Ladino clover.

	Exch. K	Exch. K + 120 K_2O	Exch. K + 300 K_2O
Bentgrass	100	100	100
Kentucky blue grass	72	93	60
Ladino clover	40	65	64
Smooth brome grass	27	58	43

Ladino clover

Kentucky blue grass

Bent grass

Figure 2. Effects of exchangeable (1), exchangeable + 120 K_2O (2) and exchangeable + 300 pounds K_2O (3) on the third cutting of Ladino clover, Kentucky blue grass and Smooth brome grass.

Group II

In comparing grass-Ladino clover combinations prior to the first cutting, clover growth was inferior to the grass in bentgrass-Ladino clover associations, and was equal to or better than the grass in Kentucky blue grass — or smooth brome grass — Ladino clover associations. No appreciable or consistent differences between soil K treatments were apparent.

Yield results of the first cutting (table 7) showed that in smooth brome grass-Ladino clover, and Kentucky bluegrass-Ladino clover combinations, yields of grass and clover were approximately equal. However, in the bentgrass-Ladino clover mixture, bentgrass outyielded the clover about 4 to 1 at all levels of soil K (table 7). Ladino clover, except when grown with bentgrass made a growth response from the addition of 60 pounds K_2O. Also, the application of 60 pounds K_2O produced a growth response in all grasses except Kentucky blue grass. The application of 120 pounds K_2O did not produce an additional yield increase by either grass or clover over that produced by 60 pounds K_2O. However, plant analysis showed that the per cent K in both grass and clover increased as soil K was increased (table 7).

After the first cutting, five of the ten pots at the exchangeable K level and five of the ten pots at the exchangeable K plus 60 K_2O level were topdressed with 60 pounds K_2O.

Observed recovery after the first cutting showed that Ladino clover made poorest growth when associated with bentgrass. Clover stands in combination with Kentucky blue grass and smooth brome grass were about equal. Both observation and yield results in the second cutting (table 8) showed that Ladino clover when in combination with bentgrass made no growth response to any of the K treatment. Plant analysis (table 8) showed that on a percentage basis, bentgrass contained about two and one-half times as much K as Ladino clover. Bentgrass also produced two to three times as much dry matter as Ladino. Thus, it would appear that bentgrass quickly reduced the soil K to a level inadequate for Ladino clover, even when K was supplied as a topdress application after the first cutting. When grown with Kentucky blue grass, Ladino clover made increased yields only on the 60 pounds K_2O topdress treatment (table 8). Observations and yield determinations showed that Ladino clover associated with smooth brome grass produced appreciable yield increases as the level of soil K was increased.

Observations showed that bentgrass made equally luxuriant growth at all K treatments. Yield results (table 8) showed that bentgrass made a growth increase only when 120 pounds K_2O was added in split applications. Kentucky blue grass (table 8) increased in yield when topdressed after the first cutting with 60 pounds K_2O and at the exchangeable K plus 120 K_2O level, but no benefit was derived from splitting the application of 120 pounds K_2O. After the first cutting, smooth brome grass made poor recovery and yields were low for all treatments.

The per cent K in the plant species increased as the soil K was increased (table 8). For all treatments, the per cent K in Ladino clover grown with bent grass was less than one per cent. Applying K_2O after the first cutting did not increase either yield or K removed by Ladino clover when grown with bentgrass, In contrast, in the second cutting, splitting the 120 pound K_2O application produced a greater yield, per cent K, and K uptake by Ladino clover with Kentucky blue grass (table 8).

Observations after the second cutting showed that the recovery of Ladino clover was best with smooth brome grass and poorest with bentgrass. Periodic observations and yields for the third cutting (table 9) showed that Ladino clover in combination with bentgrass did not respond to any K treatment. With Kentucky bluegrass, observed growth and yields (table 9) increased only in those pots which were topdressed after the first cutting.

In association with smooth brome grass, observations and yields (table 9) showed that Ladino clover responded to both the 60 and 120 pound increment of K_2O, but no additional benefit was derived from topdressing with K_2O or splitting the application of 120 pounds K_2O. As in the second cutting, bentgrass was observed to make luxuriant growth with no visible increase produced by K treatment. However, yield measurements (table 9) showed that bentgrass made appreciable growth responses when 120 pounds K_2O was added in split applications. Both growth and K uptake by Kentucky blue grass were increased as the soil K was increased. No further benefit was derived from topdressing Kentucky blue grass with K_2O after the second cutting, and yields of brome grass were very poor and were not correlated with K treatment.

In general, in the third cutting, the per cent K increased in all plant species as the soil K was increased. More consistent, however, was the increase in the milligrams of K adsorbed by the plant species as the soil K was increased. Splitting the 120 pound K_2O application produced greater yield, per cent K, and K uptake by Ladino clover associated with Kentucky blue grass (table 9). It is highly important to note that with bentgrass, the per cent K in Ladino clover was about 0.5; with Kentucky blue grass, the per cent K in Ladino clover was about 0.7; and with smooth brome grass, the per cent K in Ladino clover was about 1.0 (table 9). This shows that the grass competition for K is in the order bentgrass $>$ Kentucky blue grass $>$ smooth brome grass.

Figure 5 shows the total K uptake for three cuttings for each K treatment by Ladino clover, bentgrass, Kentucky blue grass, and smooth brome grass when the clover was grown in combination with each of the grasses. Total removal of K agrees well with theoretical K compatibility for grass-legume combinations, based on cation exchange values for roots of the species used.

As shown in table 6, K removed by bent grass with the different K treatments was 5 to 10 times greater than that removed by the associated Ladino clover, whereas K removed by Kentucky blue grass was only 1.1 to 1.7 times that removed by the associated Ladino clover. Ladino clover removed more K than did the associated bromegrass, but yields of brome grass were abnormally low.

TABLE 6

Relative uptake of K by individual plant species in grass-Ladino clover associations at different K treatments.

Soil Treatment	Association					
	Bentgrass	Ladino clover	Kentucky bluegrass	Ladino clover	Smooth brome grass	Ladino clover
Exchangeable K	100	14	40	27	26	38
Exchangeable K + 60 K_2O initially	100	16	40	36	43	43
Exchangeable K + 60 K_2O after first cutting	100	13	47	27	32	35
Exchangeable K + 60 K_2O initially + 60 K_2O after first cutting	100	11	40	35	33	40
Exchangeable K + 120 K_2O initially	100	20	42	31	36	43

It is important to note the much greater relative uptake of K by bent grass for all soil K treatments and the constancy of the relative K uptake by each of the other species, with different K treatments (table 6).

A summary of the data obtained from Group II is shown in tables 7, 8, 9, and 10, and figures 3, 4, 5.

TABLE 7

First cutting yield and composition of Ladino clover, bentgrass, Kentucky blue grass, and smooth brome grass when clover was grown in combination with each of the grasses at different K levels.*

		Exchangeable K + K_2O Treatment		
		None	60 K_2O	120 K_2O
Ladino clover	dry wt. grams	0.718	0.641	0.740
	% K	1.37	1.60	2.25
	Mgm K	9.33	9.76	17.61
bentgrass	dry wt. grams	2.762	3.286	2.937
	% K	2.61	2.73	2.90
	Mgm K	71.21	88.27	83.66
Ladino clover	dry wt. grams	1.115	1.353	0.946
	% K	1.56	1.83	2.56
	Mgm K	17.28	23.81	24.14
Kentucky blue grass	dry wt. grams	1.174	1.076	1.022
	% K	2.72	3.08	3.29
	Mgm K	31.57	32.26	32.95
Ladino clover	dry wt. grams	0.883	1.162	1.149
	% K	1.61	1.69	1.93
	Mgm K	12.77	16.48	22.69
smooth brome grass	dry wt. grams	1.244	1.681	1.541
	% K	2.40	2.93	3.25
	Mgm K	29.14	48.85	47.80

*Average of 5 replicates

TABLE 8

Second cutting yield and composition of Ladino clover, bent grass, Kentucky blue grass, and smooth brome grass when clover was grown in combination with each of the grasses at different levels of K.*

		Exchangeable K + K_2O Treatment				
		None	60 K_2O initially	60 K_2O after 1st cut.	120 K_2O initially	120 K_2O split
Ladino clover	dry wt. grams	0.964	1.034	0.937	1.024	0.899
	% K	0.66	0.66	0.74	0.94	0.84
	Mgm K	6.32	6.65	6.63	11.85	7.37
bentgrass	dry wt. grams	2.653	2.361	2.706	2.553	3.309
	% K	1.54	1.60	1.95	2.17	1.75
	Mgm K	38.90	35.32	51.57	54.79	65.56
Ladino clover	dry wt. grams	1.564	1.575	1.783	1.395	1.835
	% K	0.82	1.17	0.92	1.23	1.30
	Mgm K	12.59	19.03	16.41	18.24	24.36
Kentucky blue grass	dry wt. grams	0.972	0.965	1.634	1.254	1.285
	% K	1.54	1.58	1.75	1.75	2.16
	Mgm K	14.68	14.80	28.70	22.27	26.12
Ladino clover	dry wt. grams	1.439	1.814	1.758	1.943	2.047
	% K	1.12	1.07	1.31	1.38	1.43
	Mgm K	15.39	17.68	21.79	26.88	28.47
smooth brome grass	dry wt. grams	0.449	0.624	0.593	0.596	0.782
	% K	1.49	1.55	2.41	2.22	1.67
	Mgm K	6.08	11.39	12.78	11.56	1.477

*Average of 5 replicates

TABLE 9

Third cutting yield and composition of Ladino clover, bentgrass, Kentucky blue grass, and smooth brome grass when clover was grown in combination with each of the grasses at different levels of K.*

		Exchangeable K plus K_2O treatment				
		None	60 K_2O initially	60 K_2O after 1st cut.	120 K_2O initially	120 K_2O split
Ladino clover	dry wt. grams	1.001	1.307	1.162	1.370	0.974
	% K	0.47	0.58	0.50	0.56	0.54
	Mgm K	4.10	7.58	5.81	7.67	5.26
bentgrass	dry wt. grams	2.348	1.750	2.447	2.318	3.016
	% K	1.24	1.74	1.46	1.77	1.52
	Mgm K	29.12	30.45	35.73	41.03	45.84
Ladino clover	dry wt. grams	1.981	1.967	2.212	1.790	2.462
	% K	0.63	0.70	0.71	0.79	0.95
	Mgm K	12.48	13.80	15.71	14.14	23.39
Ky. blue grass	dry wt. grams	0.759	1.128	1.030	1.201	1.344
	% K	1.33	1.39	1.48	1.72	1.49
	Mgm K	10.09	15.68	15.24	20.66	20.03
Ladino clover	dry wt. grams	2.578	2.805	2.327	3.084	3.157
	% K	0.94	0.69	0.98	1.13	1.07
	Mgm K	24.23	25.35	22,80	34.85	33.78
smooth brome	dry wt. grams	0.159	0.512	0.300	0.233	0.318
	% K	1.54	1.15	1.73	2.71	1.33
	Mgm K	2.45	5.89	5.19	6.31	4.23

*Average of five replicates

TABLE 10

Total yield and K uptake for three cuttings of Ladino clover, bentgrass, Kentucky blue grass, and smooth brome grass when clover was grown in combination with each of the grasses at different levels of K.*

		Exchangeable K plus K_2O treatment				
		None	60 K_2O initially	60 K_2O after 1st cut	120 K_2O initially	120 K_2O split
Ladino clover	dry wt. grams	2.683	2.982	2.617	3.134	2.514
	Mgms K	19.75	23.99	21.67	37.13	22.39
bentgrass	dry wt. grams	7.763	7.397	7.915	7.808	9.611
	Mgms K	139.23	154.04	158.51	179.48	199.67
Ladino clover	dry wt. grams	4.680	4.895	5.110	4.131	5.650
	Mgm K	42.35	56.64	49.50	56.52	71.56
Ky. blue grass	dry wt. grams	2.905	3.169	3.838	3.477	3.705
	Mgm K	56.34	62.74	75.51	75.88	78.41
Ladino clover	dry wt. grams	4.900	5.771	4.968	6.176	6.366
	Mgm K	52.39	59.51	57.36	84.42	78.73
smooth brome grass	dry wt. grams	1.852	2.817	2.137	2.370	2.781
	Mgm K	37.67	66.13	47.11	65.67	67.85

*Average of five replicates

Figure 3. Effects of splitting 120 pounds K_2O on the third cutting growth of Ladino-Kentucky blue grass. (1) 120 K_2O initially (2)60 K_2O initially + 60 K_2O after first cutting.

Figure 4. Relative competition of bent grass (1), Kentucky bluegrass (2) and Smooth brome grass (3) at exchangeable level of K. Third cutting.

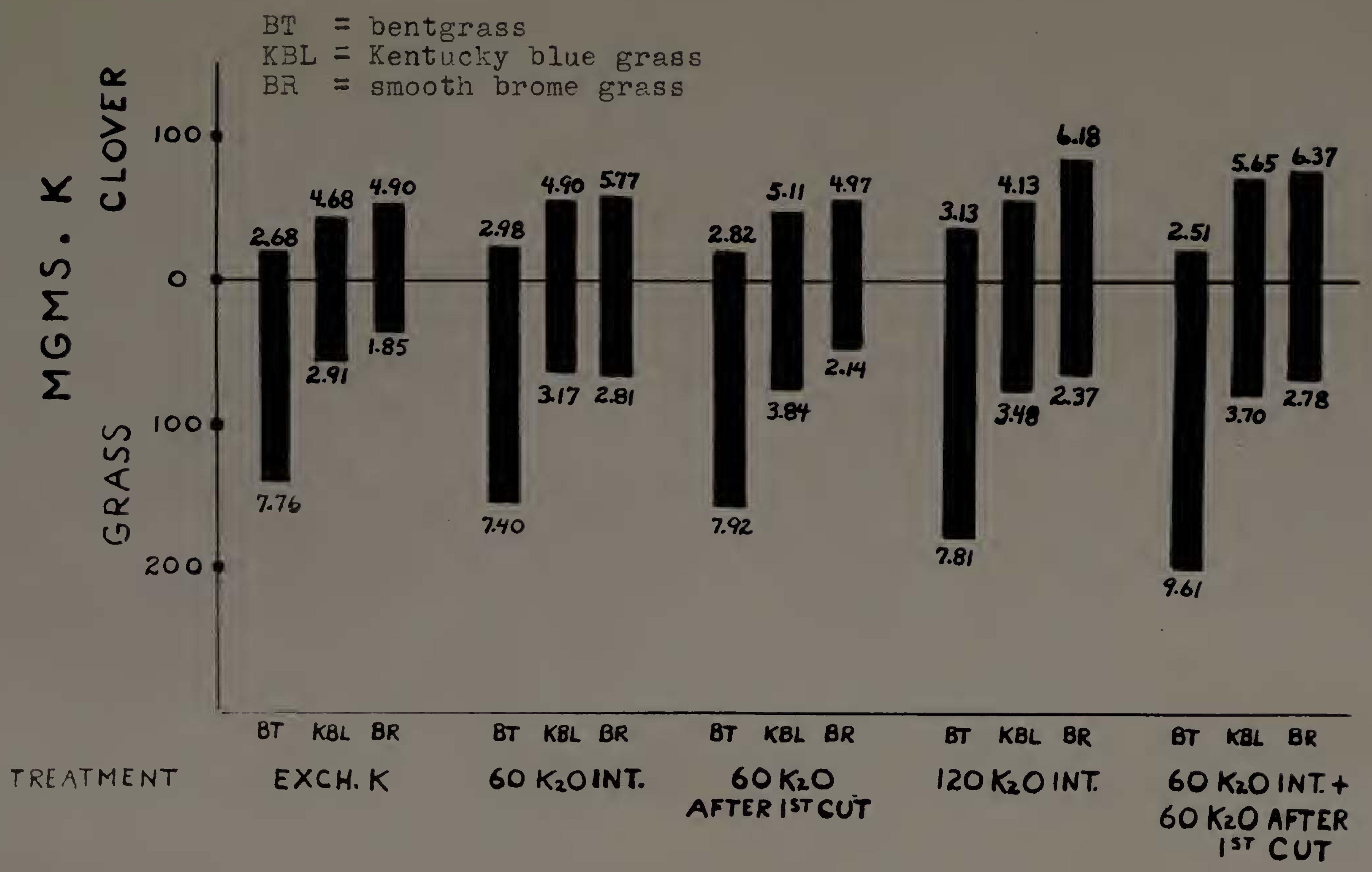

Figure 5. Total yield and K uptake for three cuttings of Ladino clover and associated grasses at different levels of K. Figures at the end of the bars represent total dry matter production in grams.

DISCUSSION OF RESULTS

Results from Group I showed that plant species differ greatly in their feeding power for soil K. For all soil K treatments, bent grass removed more K than did Kentucky blue grass, smooth brome grass, or Ladino clover (figure 1). Bentgrass adsorbed a much greater relative amount of K than the other species at the low level of soil K (table 5). As the soil K was increased, these relative differences were greatly reduced. This is in complete agreement with the fundamental relationship of cation uptake as related to cation exchange capacity of the root colloid and to the ionic concentration of the soil solution. Yields of smooth brome grass were abnormally low which explains why Ladino clover removed more K than did brome grass. The reason for the decreased growth of bent grass at the exchangeable K level before a decrease in growth of Kentucky blue grass is apparent when a comparison is made of the K uptake by these grasses. In the first two cuttings, bentgrass removed over one and one-half times as much K as did Kentucky blue grass. Thus, although bent grass was the first of the grasses to show the effects of a reduced K supply, the extremely heavy removal of K by bentgrass is in agreement with the theory. It is interesting to note that in three cuttings bentgrass at the low soil K level (132 mgm K/pot) removed more K (139 mgm/pot) than was determined to be exchangeable in the soil, indicating that non-exchangeable K was being released from the breakdown of soil minerals.

In grass-Ladino-clover combinations the order of K compatibility of the associated grasses was smooth brome grass > Kentucky blue grass >

bentgrass. For all treatments, K uptake and yields of clover were lowest when associated with bentgrass (table 10). In considering the per cent K composition in the first cutting, soil K appeared adequate to satisfy the K requirement of both grass and Ladino clover for all combinations. In some cases growth responses were produced by additional K. After the first cutting, however, competition for K became more critical and in the second cutting, per cent K in Ladino clover in combination with bent grass dropped below one per cent (table 8). In the third cutting, per cent K in combination with Kentucky blue grass also dropped below one per cent (table 9). The compatibility of the grasses studied as affecting yield and relative K content of Ladino clover is in agreement with the law of differential mono-divalent cation adsorption by cation exchangers, and the corollary that the more nearly equal the cation exchange capacities of the grass and legume roots growing in association, the more compatible will be the plants in adsorbing mineral nutrients. Results of the third cutting also showed that yields of Ladino clover associated with bentgrass increased only very slightly over the second cutting, whereas with Kentucky blue grass and smooth brome grass, clover yields increased substantially over the second cutting (tables 8 and 9). Additional data undoubtedly would have shown a reduction in the clover stands associated with bentgrass.

Sixty pounds K_2O applied after the first cutting produced a 10-20 per cent increase in the bent grass yields in the second cutting (table 8) and a 30 per cent increase in the third cutting (table 9). However, 60 pounds K_2O added after the first cutting resulted in less K uptake in the second plus third cuttings by Ladino clover with bentgrass than did 60 pounds K_2O added initially (tables 8 and 9). Likewise, split applications of 120 pounds K_2O as compared with 120 pounds K_2O added initially, decreased yields and per cent K of Ladino clover associated with bent grass in the second and third cuttings (tables 8 and 9). The lower K uptake by Ladino clover may be explained by the increased growth response and competition of the bent grass. After the first cutting, 60 pounds K_2O was not adequate to raise the soil K content to the threshold level for Ladino clover when bent grass roots were competing for K. Thus, on this soil, the bent grass competition for K cannot be overcome by applying practical amounts of K fertilizer.

In comparing Figures 1 and 5, it was noted that Ladino clover plus Kentucky bluegrass was not as effective in removing K as was either Ladino clover or Kentucky bluegrass grown alone at a given K level. Bentgrass, on the other hand, removed as much K when grown with Ladino clover as when grown alone at a given K level. Thus, it appears that Kentucky blue grass and Ladino clover handicap each other in growth and K uptake, whereas Ladino clover did not handicap bent grass.

SUMMARY AND CONCLUSIONS

A greenhouse pot experiment was conducted in which grasses with roots of different cation exchange capacity and Ladino clover were grown separately and in combination on a soil having a low level of exchangeable K. Relative differences in the feeding power for K by these plant species at different levels of applied K were studied. Also, differences in K compatibility of grasses grown in combination with Ladino clover were investigated for different K treatments. The data obtained from this experiment suggest the following conclusions:

1. Potassium uptake by individual plant species at low levels of soil K was well correlated with root cation exchange capacity, but at high levels of soil K differences in feeding power for K were reduced.
2. When the plant species were grown alone, the first increment of potash produced an increase in both yield and per cent K. Yields were not further increased by higher applications of potash, but per cent K was increased.
3. When grown with Ladino clover, the order of K compatibility was smooth brome grass > Kentucky blue grass > bentgrass.
   a. Ladino clover showed greatest growth response from increasing K treatment with smooth brome grass, but poorest with bentgrass.
   b. Per cent K in Ladino clover was lowest when associated with bentgrass and highest when associated with smooth brome grass for all K treatments.

4. As compared with 60 pounds K_2O applied initially, applying the 60 pounds K_2O as a topdressing after the first cutting decreased yield and the K uptake in the second plus third cuttings of Ladino clover when associated with bent grass.
5. As compared with 120 pounds K_2O applied initially, splitting the 120 pound K_2O application decreased the yields and per cent K in the second and third cuttings of Ladino clover associated with bent grass.
6. Thus, on this soil, the K competition of bentgrass associated with Ladino clover cannot be overcome by moderate applications of K fertilizer.

APPENDIX

The following treatments and pot numbers were used in this experiment:

Pots	Plant Species	Treatment
1-5	Ladino clover	Exchangeable K
6-10	bentgrass	"
11-15	Kentucky blue grass	"
16-20	smooth brome grass	"
21-25	Ladino clover	Exchangeable K + 120 K_2O
26-30	bentgrass	"
31-35	Kentucky blue grass	"
36-40	smooth brome grass	"
41-45	Ladino clover	Exchangeable K + 300 K_2O
46-50	bentgrass	"
51-55	Kentucky blue grass	"
56-60	smooth brome grass	"
61-65	Ladino clover - bentgrass	Exchangeable K
66-70	Ladino clover - Kentucky blue grass	"
71-75	smooth brome grass	"
76-80	Ladino clover - bent grass	Exchangeable K + 60 K_2O
81-85	Ladino clover - Kentucky blue grass	"
86-90	smooth brome grass	"
91-95	Ladino clover - bentgrass	Exchangeable K + 120 K_2O
96-100	Ladino clover - Kentucky blue grass	"
101-105	Ladino clover - smooth brome grass	"
106-110	Ladino clover - bentgrass	Exchangeable K + 60 K_2O after 1st cut.
111-115	Ladino clover - Kentucky blue grass	"
116-120	Ladino clover - smooth brome grass	"
121-125	Ladino clover - bentgrass	Exch. K + 60 K_2O + 60 K_2O after 1st cut.
126-130	Ladino clover - Kentucky blue grass	"
131-135	Ladino clover - smooth brome grass	"

The yield in grams per pot; the composition of Ladino clover, bentgrass, Kentucky blue grass, and smooth brome grass in percentages of K and Ca; milligrams of K and Ca taken up by each species per pot.

First Cutting

Pot No.	Weight in grams	Per cent K	Mgm K	Per cent Ca	Mgm Ca
1	1.634	1.59	25.98	2.47	40.30
2	1.704	1.32	22.49	2.86	48.70
3	2.324	1.08	25.10	2.58	60.00
4	1.027	1.74	17.87	2.16	22.20
5.	1.951	1.27	24.78	2.53	49.30
6	3.102	2.34	72.59	1.04	32.33
7	3.575	2.13	76.15	1.18	42.33
8	4.340	1.84	79.86	1.01	43.67
9	5.246	1.86	97.58	1.02	53.33
10	4.511	1.65	74.43	1.01	45.67
11	2.017	2.08	41.95	0.74	15.00
12	2.116	2.24	47.40	0.79	16.80
13	2.537	2.13	54.04	0.63	15.90
14	2.596	2.04	52.96	0.70	18.20
15	2.204	1.90	43.40	0.79	18.00
16	1.516	2.18	33.05	0.94	14.30
17	2.452	1.79	43.89	0.93	22.80
18	1.235	1.81	22.35	0.89	11.00
19	0.868	1.59	13.80	0.92	8.00
20	2.644	1.52	40.19	0.81	21.40
21	2.046	2.35	48.08	2.36	48.20
22	2.204	2.70	50.76	2.29	43.10
23	2.021	2.37	47.90	2.26	45.70
24	3.321	1.72	57.12	2.49	82.80
25	2.230	2.42	53.97	2.48	55.40
26	4.043	2.52	101.88	0.83	33.50
27	5.620	1.68	94.42	0.92	51.50
28	5.564	1.62	90.14	0.94	52.50
29	5.267	1.41	74.24	0.93	49.00
30	5.676	1.71	97.06	0.92	52.50
31	2.159	3.14	67.79	0.63	13.50
32	2.259	3.17	71.61	0.69	15.50
33	3.723	2.85	106.10	0.71	26.33
34	1.694	3.44	58.27	0.66	11.10
35	3.620	2.69	97.38	0.54	19.67
36	3.238	2.76	89.37	0.78	25.33
37	3.438	2.88	99.01	0.85	29.33
38	3.078	2.87	88.33	0.96	29.67
39	2.869	2.50	71.72	0.74	21.33
40	2.946	2.98	87.79	0.87	25.67

Pot No.	Weight in grams	Per cent K	Mgm K	Per cent Ca	Mgm Ca
41	2.060	3.27	67.36	3.06	42.40
42	2.077	3.18	66.05	2.43	50.50
43	2.335	2.63	61.41	2.41	56.20
44	2.448	3.08	75.40	2.25	55.00
45	0.837	3.08	25.78	2.20	18.40
46	3.868	3.85	148.92	0.83	32.00
47	5.200	2.13	110.76	0.80	41.50
48	5.805	1.77	102.75	0.85	46.00
49	5.410	2.38	128.76	0.75	40.50
50	5.939	1.29	76.61	0.76	45.00
51	2.418	3.45	83.42	0.58	14.00
52	0.854	4.22	36.03	0.76	6.46
53	1.897	2.97	56.34	0.68	13.00
54	3.528	3.49	123.13	0.54	19.33
55	3.883	2.40	93.19	0.52	20.33
56	1.971	3.50	68.99	0.71	14.00
57	3.367	3.17	106.73	0.71	24.00
58	2.936	4.16	122.13	0.74	21.67
59	4.096	2.06	84.38	0.75	30.67
60	2.486	3.87	96.21	0.79	19.67

Pot No.	Wt. clover in grams	% K	Mgm K	% Ca	Mgm Ca	Wt. grass in grams	% K	Mgm Ca	% Ca	mgm Ca
61	0.533	1.43	7.63	2.77	14.82	1.184	3.12	36.90	1.08	12.75
62	0.741	1.09	8.10	2.29	16.96	3.932	2.19	86.00	1.04	40.80
63	0.542	1.15	6.25	2.64	19.50	1.889	2.13	40.25	1.03	19.46
64	1.194	1.50	17.94	2.18	26.03	3.333	2.65	88.30	0.90	30.00
65	1.311	1.08	14.20	2.61	34.22	2.632	2.68	70.20	0.90	23.69
66	1.165	1.21	14.10	3.46	40.31	0.729	2.98	21.75	0.70	5.10
67	0.703	1.25	8.80	3.07	21.60	1.567	2.75	43.10	0.63	9.90
68	1.062	—	—	—	—	1.132	—	—	0.71	8.00
69	1.022	1.73	17.72	3.36	34.34	0.527	2.81	14.83	0.58	3.05
70	1.497	1.50	22.47	2.74	41.00	1.408	2.65	37.33	0.63	8.87
71	1.189	1.43	16.97	2.39	28.42	0.558	2.25	12.58	1.10	6.14
72	0.765	1.91	14.63	3.88	29.65	0.738	2.86	21.13	1.04	7.70
73	0.526	2.33	12.25	2.12	11.15	0.870	2.99	26.00	1:01	8.80
74	0.298	1.97	5.88	2.45	7.30	1.853	2.59	48.00	0.78	14.50
75	1.810	0.85	15.33	1.54	27.87	1.488	2.45	36.50	0.63	9.40
76	0.952	1.11	10.58	2.38	22.66	3.302	2.73	90.00	0.98	32.36
77	0.520	1.46	7.60	2.52	13.10	3.424	2.89	99.00	0.95	32.53
78	1.062	1.48	15.60	2.00	21.24	1.717	3.29	56.50	1.02	17.51
79	0.039	1.26	0.50	2.41	0.94	4.436	2.40	106.50	0.99	43.92
80	0.629	1.52	10.33	2.42	15.22	3.193	2.93	93.50	0.99	31.61

Pot. No.	Wt. clover in grams	% K	Mgm K	% Ca	Mgm Ca	Wt. grass in grams	% K	Mgm K	% Ca	Mgm Ca
81	0.711	2.28	16.18	2.18	15.50	0.630	3.22	20.30	0.71	4.47
82	2.275	2.11	47.60	2.61	59.38	0.375	3.83	14.38	0.73	2.74
83	0.997	2.05	20.40	2.14	21.34	0.888	3.31	29.40	0.71	6.30
84	1.419	1.72	24.47	2.11	29.94	1.381	2.83	39.10	0.62	8.56
85	1.952	1.43	27.80	2.36	46.07	1.333	3.11	41.50	0.62	8.29
86	0.165	1.95	3.22	2.44	4.03	2.543	2.94	74.80	0.75	19.07
87	0.647	1.93	12.50	2.53	16.37	1.617	3.15	51.00	0.92	14,88
88	0.994	1.29	12.80	2.69	26.74	1.644	2.70	44.35	0.62	10.19
89	1.490	1.66	24.80	2.06	30.69	1.009	2.94	29.63	0.81	8.17
90	1.990	1.24	24.07	2.51	49.95	1.697	2.45	41.50	0.91	15.44
91	0.850	2.35	20.37	2.19	18.62	2.302	3.18	73.30	1.01	23.25
92	0.662	2.18	14.47	2.73	18.07	2.786	3.32	92.60	0.90	25.07
93	0.334	1.87	6.25	2.00	6.68	4.166	2.45	102.00	0.80	33.33
94	1.152	2.85	32.80	2.55	29.38	2.620	2.99	78.40	0.84	22.01
95	0.702	2.02	14.17	2.62	18.39	2.813	2.56	72.00	0.95	26.72
96	0.928	1.78	16.50	2.54	23.57	0.973	2.98	29.50	0.75	7.30
97	1.083	2.88	30.20	2.41	26.10	0.558	3.78	21.10	0.79	4.41
98	1.117	1.88	20.95	2.36	26.36	1.629	2.98	48.60	0.66	10.75
99	0.643	2.59	16.63	2.52	16.20	1.102	3.40	37.50	0.66	7.27
100	0.959	3.67	36.40	2.01	19.28	0.846	3.32	28.07	0.58	4.90
101	0.779	1.98	15.40	2.48	19.32	1.616	3.35	54.15	0.63	10.18
102	0.623	1.80	11.25	2.92	18.19	0.786	2.99	23.53	0.87	6.54
103	1.107	2.24	24.80	2.21	24.46	1.053	3.80	40.00	0.81	8.53
104	2.327	2.04	47.50	2.34	54.60	1.173	3.67	43.10	0.78	9.10
105	0.910	1.60	14.50	2.73	24.80	3.177	2.46	78.20	0.76	24.30
106	0.331	1.68	5.56	2.98	9.86	1.732	2.79	48.25	1.24	21.50
107	0.892	1.00	8.94	2.34	20.84	2.370	2.41	57.20	1.11	26.30
108	0.103	1.65	1.70	2.22	2.29	3.647	2.54	92.50	1.00	37.60
109	0.559	1.57	8.78	2.11	11.79	3.486	2.90	101.00	1.04	36.10
110	0.961	1.48	14.20	2.75	26.43	3.408	2.68	91.50	0.95	32.30
111	1.161	1.19	13.76	2.86	33.20	0.810	2.58	20.80	0.82	6.64
112	1.269	1.53	19.46	2.41	30.58	0.817	2.60	21.23	0.73	5.96
113	1.229	1.51	18.60	2.51	30.90	1.384	2.60	35.93	0.85	11.76
114	1.687	1.40	23.67	2.42	40.80	1.221	2.40	29.33	0.85	10.38
115	0.349	1.46	5.12	2.55	8.90	2.136	2.59	55.25	0.73	15.50
116	0.765	2.04	15.60	2.27	17.37	0.098	2.89	2.83	1.08	1.06
117	0.783	1.53	11.95	2.77	21.69	0.600	2.06	12.33	1.15	6.90
118	0.304	1.53	4.76	2.10	6.38	2.030	2.98	60.50	0.89	18.07
119	0.994	1.57	9.18	2.40	23.86	2.764	1.63	45.00	0.65	17.97
120	1.445	0.92	21.17	2.56	37.00	1.436	1.85	26.53	0.66	9.48
121	0.676	1.10	7.46	2.79	18.86	2.732	2.50	68.30	0.99	27.05
122	0.223	1.89	4.22	2.56	5.71	3.461	2.65	91.72	0.94	32.53
123	1.174	1.36	15.93	2.28	26.77	3.061	2.46	75.40	0.94	28.77
124	0.648	1.20	7.75	2.68	17.37	3.615	2.85	103.00	0.91	32.90
125	0.490	3.62	17.75	4.00	19.60	3.916	2.52	98.80	0.62	24.28

Pot No.	Wt. clover in grams	% K	Mgm K	% Ca	Mgm Ca	Wt. grass in grams	% K	Mgm K	% Ca	Mgm Ca
126	0.893	2.19	19.60	2.46	21.97	0.624	3.53	22.05	0.68	4.24
127	1.659	1.66	27.50	2.91	48.28	0.991	2.84	28.17	0.81	8.03
128	0.510	2.06	10.50	2.34	11.93	1.590	2.73	43.45	0.88	13.99
129	1.792	1.67	30.00	2.90	51.97	1.480	2.89	42.75	0.51	7.55
130	1.322	1.06	14.00	1.46	19.30	1.464	2.45	41.50	0.58	8.49
131	1.198	2.10	25.10	2.52	30.19	1.014	3.09	29.60	0.87	8.82
132	1.490	1.56	23.17	2.20	32.78	1.347	2.92	47.85	0.67	9.02
133	1.513	1.05	15.80	2.65	40.09	2.683	3.55	73.30	0.63	16.90
134	0.556	2.01	11.15	2.12	11.79	2.055	2.73	63.50	0.72	14.80
135	0.583	2.08	12.15	2.73	15.92	1.197	2.75	32.93	0.74	8.86

Second Cutting

Pot No.	Weight in grams	Per cent K	Mgm K	Per cent Ca	Mgm Ca
1	2.053	0.71	14.67	3.17	68.08
2	2.250	0.71	16.07	3.17	71.33
3	2.653	0.70	18.68	3.00	79.59
4	1.770	0.88	15.73	2.75	48.68
5	2.309	0.72	16.67	3.82	88.20
6	3.635	1.10	39.99	0.95	34.53
7	3.296	1.19	39.06	0.99	32.63
8	4.898	0.80	39.18	0.76	37.22
9	3.964	0.88	34.69	1.07	42.41
10	3.684	0.92	33.89	0.87	32.05
11	2.739	1.00	27.39	0.61	16.71
12	2.235	0.64	15.25	0.73	16.32
13	3.473	1.04	36.12	0.70	24.31
14	2.594	0.68	17.64	0.76	19.71
15	2.427	1.25	30.40	0.81	19.66
16	0.113	1.15	1.30	1.46	1.65
17	1.640	0.83	13.60	0.63	10.33
18	0.097	1.43	1.39	1.49	1.45
19	0.361	1.11	3.99	0.77	2.78
20	0.628	1.07	6.75	1.74	10.93
21	2.046	1.35	27.60	2.41	49.31
22	2.628	1.47	38.60	2.63	69.12
23	2.716	1.28	34.71	2.75	74.69
24	3.571	1.20	42.85	2.59	92.49
25	2.401	1.37	32.80	2.76	66.27
26	3.249	1.76	57.18	0.81	26.32
27	4.126	1.36	56.11	0.85	35.07
28	4.534	1.45	65.74	0.68	30.83
29	4.434	1.27	56.31	0.80	35.47
30	4.796	1.23	58.99	0.44	21.10
31	2.051	1.29	26.50	0.60	12.31
32	3.213	1.88	60.40	0.54	17.35
33	3.377	1.57	53.02	0.58	19.59
34	2.550	2.13	54.32	0.54	13.77
35	4.025	1.46	58.77	0.53	21.33
36	0.925	1.81	16.75	0.92	8.51
37	1.304	1.25	16.27	0.78	10.71
38	1.532	2.11	32.38	0.73	11.18
39	0.578	1.48	8.57	0.65	3.76
40	1.271	2.15	27.33	0.80	10.17

Pot No.	Weight in grams	Per cent K	Mgm K	Per cent Ca	Mgm Ca
41	3.355	2.04	68.44	2.34	78.51
42	2.317	2.40	48.00	2.35	54.45
43	3.021	2.41	72.87	2.34	70.69
44	2.886	2.13	61.47	2.11	60.89
45	2.152	2.65	57.00	2.28	49.07
46	4.473	2.69	120.32	0.53	23.71
47	4.498	2.36	106.15	0.51	22.94
48	4.180	2.46	102.73	0.62	25.92
49	5.244	2.71	142.11	0.59	30.94
50	3.949	2.11	83.32	0.51	20.14
51	1.013	1.62	16.40	0.91	9.22
52	0.504	2.43	12.25	0.66	3.33
53	2.040	2.24	45.70	0.64	13.06
54	3.713	2.23	82.80	0.52	19.31
55	3.241	2.34	75.84	0.45	14.50
56	0.447	3.30	14.75	0.80	3.58
57	1.114	2.34	26.07	0.76	8.47
58	0.641	2.89	18.50	0.43	2.76
59	2.107	1.98	41.70	0.68	14.33
60	0.513	2.80	14.25	1.00	5.13

Pot No.	Wt. clover in grams	% K	Mgm K	% Ca	Mgm Ca	Wt. grass in grams	% K	Mgm K	% Ca	Mgm Ca
61	0.948	0.69	6,50	3.59	34.03	1.554	1.[illegible]9	29.40	0.90	13.99
62	0.757	0.43	3.24	3.31	25.06	3.741	1.13	42.27	0.83	31.05
63	0.601	0.81	4.88	3.29	19.77	3.001	1.22	36.61	0.77	23.11
64	1.225	0.76	0.33	3.09	37.85	2.793	1.72	48.04	0.71	19.83
65	1.291	0.59	7.67	3.35	43.25	2.177	1.75	38.20	0.78	16.98
66	1.999	0.83	16.60	3.49	69.77	0.996	1.43	14.25	0.58	5.78
67	1.135	0.86	9.73	3.08	34.96	1.792	1.37	24.60	0.64	11.47
68	1.735	—	—	—	—	0.945	—	—	—	—
69	1.655	0.85	14.00	3.74	61.90	0.464	1.22	5.67	0.91	4.22
70	1.395	0.75	10.04	3.02	42.13	0.661	2.15	14.20	0.60	3.97
71	1.915	0.78	15.00	3.38	64.73	0.367	1.08	3.97	0.57	2.09
72	1.139	1.16	13.20	3.06	34.82	0.484	1.97	9.54	0.76	3.68
73	1.323	1.41	18.73	2.44	32.28	0.199	1.69	3.36	0.83	1.65
74	1.083	1.41	15.27	2.75	29.78	0.414	1.23	5.08	1.12	4.64
75	1.736	0.85	14.75	3.22	55.90	0.781	1.47	11.47	0.60	4.69
76	1.400	0.55	7.67	3.38	47.32	2.141	1.28	19.17	0.91	19.48
77	0.958	0.69	6.60	3.65	34.97	2.239	1.77	39.60	0.98	21.94
78	1.379	0.90	12.47	3.09	42.61	1.578	1.99	31.40	0.92	14.52
79	0.117	0.54	0.63	—	—	2.865	1.29	36.96	0.87	24.93
80	0.956	0.62	5.90	3.09	29.54	2.981	1.66	49.48	0.82	24.44

Pot No.	Wt. clover in grams	% K	Mgm K	% Ca	Mgm Ca	Wt. grass in grams	% K	Mgm K	% Ca	Mgm Ca
81	1.095	1.56	17.00	2.53	27.70	0.646	1.06	6.85	0.33	2.13
82	2.266	1.57	35.50	2.63	59.60	0.543	—	—	1.07	5.81
83	1.777	1.53	23.60	2.17	38.56	1.089	1.96	2.147	0.80	8.71
84	1.284	0.90	11.60	3.13	40.19	1.132	1.58	17.93	0.63	7.13
85	1.455	0.51	7.47	3.44	50.04	1.415	1.74	24.60	0.75	10.61
86	0.256	1.56	3.96	3.12	7.99	0.547	1.95	10.65	0.94	5.14
87	1.084	0.90	9.80	2.85	30.89	1.607	1.76	28.40	0.77	12.37
88	2.260	0.95	21.50	3.74	84.52	0.248	1.01	2.50	1.25	3.10
89	2.527	1.04	26.28	2.89	73.03	0.448	—	—	1.10	4.93
90	2.941	0.91	26.86	3.10	91.17	0.270	1.48	4.00	1.25	3.38
91	1.751	1.08	19.00	2.22	38.87	2.078	2.81	58.40	0.78	16.21
92	0.729	0.85	6.80	2.76	20.12	2.494	2.05	51.20	0.87	21.70
93	0.477	0.93	4.45	2.88	13.74	4.129	1.48	61.11	0.65	26.84
94	2.099	0.93	19.50	2.90	60.87	1.478	2.74	40.50	0.74	10.94
95	1.062	0.89	9.47	2.90	30.80	3.585	1.75	62.74	0.65	23.30
96	1.503	1.28	19.27	2.11	31.71	1.291	1.79	26.93	0.71	9.17
97	1.329	1.39	18.47	2.51	33.36	0.917	2.09	19.20	0.59	5.41
98	1.413	1.01	14.33	2.78	39.28	1.424	1.31	18.60	0.58	8.26
99	1.661	1.25	20.90	2.42	40.20	1.352	1.80	24.33	0.40	5.41
100	1.069	—	—	2.22	23.73	1.287	—	—	0.44	5.66
101	1.563	1.71	26.80	2.60	40.64	0.603	2.52	17.44	0.74	5.13
102	1.027	1.48	15.20	2.89	29.68	0.157	2.62	4.11	0.86	1.35
103	2.267	1.28	29.00	2.78	63.02	0.405	2.65	10.75	0.69	2.79
104	3.091	1.51	15.07	2.02	62.44	0.539	2.10	11.30	0.54	2.91
105	1.766	0.94	16.60	3.15	55.63	1.185	1.20	14.20	0.63	7.47
106	0.633	0.83	5.24	3.24	20.51	2.153	2.26	48.70	0.94	20.24
107	1.644	0.57	9.33	2.89	47.51	2.022	1.96	39.65	1.02	20.62
108	0.227	0.73	1.64	3.35	7.60	3.977	1.70	67.61	0.73	29.03
109	0.769	0.85	6.50	2.41	18.53	2.847	1.64	46.69	0.81	23.06
110	1.412	0.74	10.43	3.54	49.98	2.531	2.18	55.18	0.82	20.75
111	1.475	0.80	11.73	2.27	33.48	1.305	1.83	23.87	0.71	9.27
112	2.210	0.98	21.60	2.88	63.25	1.069	1.69	18.05	0.67	7.16
113	1.931	0.95	18.30	2.86	55.23	1.783	1.86	33.10	0.53	9.45
114	2.467	0.92	22.60	2.55	62.91	1.696	1.64	28.00	0.64	10.85
115	0.821	0.95	7.84	3.10	25.45	2.317	1.75	40.50	0.69	15.99
116	1.378	1.84	25.33	1.74	23.98	0.159	2.95	4.69	1.03	1.64
117	1.715	1.41	24.10	3.18	54.54	0.084	2.90	2.44	1.09	—
118	0.911	1.38	12.60	2.48	22.59	0,934	2.79	26.05	0.64	5.98
119	2.248	0.78	17.50	2.85	64.07	1.066	1.80	19.20	0.77	8.21
120	2.536	1.16	29.42	2.74	69.49	0.721	1.60	11.50	0.64	4.61

Pot No.	Wt. clo-ver in grums	% K	Mgm K	% Ca	Mgm Ca	Wt. grass in grams	% K	Mgm K	% Ca	Mgm Ca
121	0.853	0.78	6.63	3.41	29.09	3.637	1.97	71.65	0.81	29.46
122	0.558	0.98	5.48	3.18	17.74	3.714	2.04	75.77	0.92	34.17
123	1.067	0.74	7.90	3.11	33.18	4.122	1.89	87.91	0.64	26.38
124	1.124	0.66	7.47	3.39	38.10	1.648	1.21	36.00	1.41	23.24
125	0.894	1.05	9.36	3.19	28.52	3.423	1.65	56.48	0.52	17.80
126	1.734	1.82	31.60	2.58	44.74	0.497	2.78	13.80	1.57	7.80
127	2.992	1.32	39.49	2.78	83.18	0.857	2.19	18.75	0.81	6.94
128	0.477	1.30	6.20	2.46	11.73	1.917	1.80	34.60	0.85	16.29
129	2.227	0.93	20.70	3.18	70.81	1.218	2.07	25.20	0.61	7.43
130	2.107	1.13	23.80	2.90	61.10	1.936	1.98	38.25	0.56	10.84
131	2.380	1.43	34.00	0.97	23.09	0.253	1.05	2.66	0.40	1.01
132	2.844	1.22	34.80	1.91	5.432	0.817	2.08	17.00	0.56	4.58
133	2.272	1.18	25.80	2.94	66.80	0.665	1.41	9.40	0.50	3.33
134	1.080	1.23	13.27	2.46	26.57	1.391	2.15	30.00	0.68	9.46
135	1.659	2.08	34.50	2.59	42.97	—	—	—	—	—

Third Cutting

Pot No.	Dry weight in grams	% K	Mgm K	% Ca	Mgm Ca
1	1.047	0.61	6.37	2.54	26.59
2	2.429	0.55	13.43	2.82	68.38
3	2.542	0.49	12.35	2.22	56.55
4	2.501	0.55	13.65	2.65	66.20
5	2.988	0.79	23.60	3.08	91.75
6	2.429	1.00	24.29	1.23	28.88
7	2.581	1.05	27.10	1.20	30.97
8	3.219	0.47	15.13	0.89	28.65
9	2.270	0.92	20.98	1.21	27.47
10	3.207	0.60	19.24	0.81	25.97
11	2.615	1.04	27.20	0.68	17.78
12	2.633	0.90	23.70	0.65	17.11
13	3.591	0.92	33.04	0.81	29.09
14	1.953	1.00	19.60	0.75	14.65
15	3.880	0.60	23.28	0.65	24.82
16	—	—	—	—	—
17	0.217	0.87	1.89	1.16	2.52
18	0.059	—	—	—	—
19	0.208	1.13	2.34	1.39	2.89
20	0.148	1.04	1.54	1.38	2.04
21	2.844	1.16	33.10	2.33	66.27
22	4.406	1.07	47.20	2.49	109.71
23	2.670	1.00	26.80	2.50	66.75
24	4.707	0.97	45.60	2.94	138.60
25	2.855	1.29	36.95	2.43	69.30
26	3.813	1.32	50.33	0.85	32.41
27	3.552	1.23	43.69	0.93	33.03
28	3.684	1.01	37.21	0.83	30.58
29	3.141	1.17	36.75	0.97	30.47
30	4.111	0.96	39.47	0.71	29.19
31	2.245	1.69	37.93	0.57	12.67
32	3.295	1.34	44.15	0.52	17.13
33	4.135	1.15	47.55	0.51	21.09
34	4.035	1.67	67.38	0.57	23.00
35	4.061	1.00	40.61	0.48	19.49
36	0.428	1.36	5.81	0.89	2.30
37	0.352	0.98	3.44	0.80	4.28
38	0.542	1.76	9.56	0.93	2.14
39	0.471	1.56	7.33	1.23	5.42
40	0.146	1.84	2.69	1.25	2.03
41	3.447	1.54	53.00	1.74	60.00
42	3.907	1.95	76.20	1.81	70.50
43	3.191	2.19	69.80	1.97	63.00
44	4.435	1.74	77.20	1.83	81.30
45	3.452	2.38	82.30	1.97	67.80

Pot No.	Dry Weight in grams	% K	Mgm K	% Ca	Mgm Ca
46	3.769	2.22	83.67	1.12	42.21
47	3.998	2.16	86.36	0.57	22.39
48	3.490	1.96	68.40	0.58	20.24
49	4.401	1.70	74.82	0.65	28.61
50	3.181	1.87	59.48	0.63	20.04
51	0.582	2.38	13.85	0.63	3.67
52	0.711	2.38	16.90	0.63	4.48
53	2.449	2.29	56.10	0.50	12.25
54	4.790	1.98	94.84	0.41	19.64
55	3.449	2.06	70.05	0.46	15.87
56	0.259	3.22	8.35	0.89	2.31
57	0.535	2.56	13.72	0.80	4.28
58	0.231	3.07	7.09	0.93	2.15
59	0.442	2.33	10.31	1.23	5.44
60	0.162	2.52	4.08	1.25	2.03

Pot No.	Wt. clover in grams	% K	Mgm K	% Ca	Mgm Ca	Wt. grass in grams	% K	Mgm K	% Ca	Mgm Ca
61	1.353	0.59	8.00	2.57	34.80	1.057	1.42	15.00	1.04	10.97
62	0.617	0.44	2.73	2.47	15.25	2.654	0.96	25.48	0.97	25.74
63	0.486	0.59	2.85	2.42	11.75	3.296	1.08	35.60	0.82	27.03
64	1.238	0.42	5.20	2.65	32.80	1.929	1.23	23.75	0.83	16.00
65	1.310	0.31	4.08	2.87	37.60	2.804	1.51	42.34	0.83	23.27
66	2.550	0.62	15.90	3.24	82.50	0.822	0.85	6.90	0.56	4.58
67	1.179	0.58	6.85	2.76	32.54	1.620	0.82	13.34	0.62	9.92
68	2.376	—	—	—	—	0.900	—	—	0.71	6.43
69	1.711	0.63	10.78	—	—	0.303	1.81	5.48	1.01	3.08
70	2.090	0.70	14.63	2.65	55.50	0.152	1.84	2.79	0.84	1.28
71	2.683	0.67	18.00	2.89	77.54	0.129	1.11	1.43	0.47	0.75
72	1.888	1.13	21.25	2.49	47.00	0.109	1.59	1.73	0.96	1.05
73	2.858	1.01	29.00	2.23	63.67	0.101	1.98	2.00	1.30	1.31
74	2.828	1.05	29.60	2.31	65.33	0.154	1.32	2.03	1.17	1.81
75	2.631	0.82	21.53	2.54	66.67	0.303	1.69	5.11	0.82	2.70
76	1.407	0.52	7.36	3.04	42.80	1.680	1.60	26.80	1.14	19.33
77	1.226	0.45	5.50	3.13	38.40	2.232	1.64	36.60	1.07	23.85
78	1.571	0.51	8.04	3.25	51.06	1.370	1.59	21.83	0.99	13.57
79	0.079	—	—	—	—	1.642	2.28	37.52	1.92	31.60
80	1.024	0.84	8.60	2.54	26.00	1.828	1.57	28.75	0.94	17.25

Pot No.	Wt. clover in grams	% K	Mgm K	% Ca	Mgm Ca	Wt. grass in grams	% K	Mgm K	% Ca	Mgm Ca
81	1.401	1.05	14.64	2.23	31.20	0.574	1.38	7.90	0.71	4.10
82	3.265	0.54	17.73	2.14	69.87	0.548	1.23	6.75	0.61	3.35
83	2.134	0.86	18.25	1.99	42.50	0.983	1.61	15.92	0.95	9.33
84	1.839	0.53	9.80	2.66	49.00	1.471	1.38	20.30	0.61	8.90
85	1.198	0.52	6.20	2.54	30.40	2.062	1.33	27.40	0.74	15.35
86	0.700	0.81	5.67	3.24	22.67	0.291	0.72	2.11	1.09	3.16
87	2.499	0.68	17.13	2.84	70.50	1.121	1.46	16.33	0.73	8.20
88	2.988	0.78	23.17	2.77	82.67	0.079	—	—	—	—
89	4.181	0.61	25.30	2.94	123.00	0.125	1.26	1.57	1.28	1.60
90	3.659	0.56	20.50	3.16	115.62	0.020	—	—	—	—
91	1.960	0.60	11.83	2.27	44.49	1.121	2.05	23.00	0.83	9.80
92	0.775	0.65	5.00	2.58	20.00	1.954	1.92	37.50	0.95	18.50
93	0.365	0.56	2.04	2.99	10.91	3.662	1.09	39.02	0.73	26.73
94	2.821	0.60	16.83	2.79	70.71	0.910	2.46	22.40	0.98	8.88
95	0.928	0.40	3.70	2.91	27.00	3.921	1.31	51.37	0.73	28.62
96	1.691	1.01	17.08	2.04	34.50	1.150	1.69	19.40	0.58	6.56
97	1.742	1.23	21.43	2.06	36.00	0.549	1.69	9.28	0.58	3.20
98	2.200	0.72	15.84	2.29	50.50	0.692	—	—	—	—
99	2.028	0.97	19.67	2.02	41.00	1.600	1.79	28.66	0.60	9.52
100	1.291	—	—	1.46	18.80	1.811	—	—	0.47	8.50
101	2.951	1.12	32.93	1.98	48.43	0.241	2.60	6.26	0.77	1.85
102	2.021	1.16	23.50	2.40	48.50	0.290	3.07	8.90	1.97	2.80
103	3.038	1.14	34.57	2.28	69.27	0.159	2.94	4.68	0.91	1.45
104	4.201	1.06	44.60	2.26	84.98	0.121	2.28	2.76	1.69	2.04
105	3.209	1.05	46.83	3.09	99.33	0.352	—	—	1.07	3.76
106	1.239	0.52	6.50	3.39	42.00	1.812	1.77	32.13	0.89	16.20
107	1.637	0.46	7.45	2.28	37.32	2.199	1.26	27.70	1.02	22.53
108	0.265	0.48	1.26	3.02	8.00	3.469	1.19	41.28	0.83	28.27
109	0.969	0.55	5.35	2.32	22.50	2.386	1.42	33.88	0.82	19.57
110	1.701	0.50	8.55	2.91	49.50	2.370	1.67	39.58	0.82	19.43
111	1.272	0.48	6.15	3.49	44.39	1.562	1.41	22.08	0.67	10.50
112	2.771	0.70	19.40	2.65	73.50	0.748	1.43	10.87	0.63	4.70
113	2.545	0.73	18.55	2.82	71.77	1.308	1.68	22.00	0.61	7.92
114	3.010	0.78	23.53	2.39	72.00	1.188	1.58	18.80	0.71	8.48
115	1.461	0.85	12.45	2.95	43.10	0.345	1.28	4.34	1.27	4.38
116	2.042	1.57	32.08	1.86	38.00	0.201	1.43	2.88	1.03	2.08
117	2.371	1.00	23.70	2.77	65.68	0.011	—	—	—	—
118	1.942	0.92	19.25	2.45	47.50	0.732	1.88	13.77	0.61	4.43
119	2.265	0.60	13.63	2.61	59.12	0.400	1.71	6.85	0.87	3.46
120	3.017	0.75	22.67	2.52	76.00	0.157	1.92	3.01	0.64	1.01

Pot No.	Wt. clover in grams	% K	Mgm K	% Ca	Mgm Ca	Wt. grass in grams	% K	Mgm K	% Ca	Mgm Ca
121	0.834	0.48	4.00	2.19	18.33	2.850	1.41	40.19	0.72	20.52
122	0.839	0.42	3.50	3.22	27.00	3.174	1.29	40.94	1.14	36.18
123	0.778	0.48	3.73	2.55	19.84	2.844	1.58	44.94	0.65	18.49
124	1.364	0.60	8.12	2.84	38.74	3.995	1.98	79.10	0.78	34.76
125	1.057	0.73	7.74	3.18	33.61	2.218	1.35	30.00	0.69	15.47
126	3.042	1.10	33.47	2.55	77.57	0.707	1.88	13.33	0.61	4.30
127	3.521	0.97	34.00	2.53	89.00	0.339	1.20	4.08	0.82	2.78
128	0.829	1.00	8.29	2.53	21.00	2.763	1.40	38.68	0.74	20.45
129	2.631	0.67	17.60	2.66	69.98	1.306	1.35	17.63	0.64	8.30
130	2.295	0.99	22.55	2.38	54.38	1.603	1.62	25.92	0.60	9.64
131	3.321	0.94	31.25	2.70	89.67	0.051	—	—	—	—
132	4.150	1.04	43.00	1.93	80.00	0.070	—	—	—	—
133	2.840	0.80	22.83	2.26	64.00	0.239	1.33	3.18	—	—
134	2.061	1.13	23.25	2.16	44.50	1.190	1.32	15.71	0.57	6.73
135	3.411	1.46	49.75	2.53	86.30	0.042	—	—	—	—

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