NITROGEN AND MINERAL CONSTITUENTS OF THE ALFALFA PLANT

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NITROGEN AND MINERAL CONSTITUENTS OF THE ALFALFA PLANT

BY J. W. AMES AND GEO. E. BOLTZ

The adaptability of the alfalfa plant to various conditions of soil and climate renders it of considerable importance. Alfalfa thrives best upon calcareous soil, but a deficiency of calcium carbonate is not the only factor which limits the growth and yield of this crop. From the large amounts of other mineral elements which it contains it is readily apparent that these elements also must be supplied, either naturally or artificially through the soil medium for the plant to attain its maximum development.

This bulletin presents data secured from a study of the mineral elements of the alfalfa plant grown on soil under conditions which have produced marked variations in the yield and composition of the crop.

Attention has been directed to (1) effect of phosphorus when used alone, and in combination with potassium and nitrogen; (2) influence of quantity of lime applied to the soil; (3) variation in first and second cuttings; (4) amounts of mineral elements soluble in water; and (5) separation of the nitrogen and phosphorus bodies.

It is recognized that the composition of any crop, so far as the mineral elements are concerned, does not represent the amount of the different substances the plant may have assimilated from the soil during its growth; for it has been clearly demonstrated by different investigators that considerable amounts of potassium, phosphorus and nitrogen are removed by rain and dew. The amounts which are removed from the soil, however, will be fairly represented by the composition of the plant if the samples of the crop are taken at the time of harvesting.

CROPS ANALYZED

The samples used for this work were secured from the first and second cuttings of alfalfa grown on the silt loam soil of this Station. Without previous treatment with lime, this soil is not adapted to the successful growing of alfalfa, even though other known conditions are favorable. Samples were obtained from differently fertilized plots which were treated with two different quantities of lime, as is shown in the following tables. These plots were seeded in 1905 and are a part of the alfalfa investigations conducted by the Department of Agronomy under the direction of Prof. C. G. Williams.

Wherever the mineral forms of phosphorus, potassium and nitrogen were applied, these were carried by 320 pounds of acid phosphate, 60 pounds muriate of potash and 80 pounds nitrate of soda per acre. Two plots received barnyard manure at the rate of 16,000 pounds per acre. The plots were treated in 1903 and in 1907 with the amounts of the fertilizers and manure indicated above, while in 1909 they received only half of the usual amounts of fertilizer and manure; in 1910 mineral fertilizers were applied to the plots receiving such in previous treatment but no manure was applied to the manure plots. For a more detailed description of the fertilizer treatment, the reader is referred to Bulletin 181 of this Station.

COMPOSITION OF ALFALFA AND OTHER CROPS COMPARED

The analysis of the alfalfa plant shows that nitrogen is present in the largest amount, followed by potassium, calcium, magnesium, sulphur and phosphorus. Alfalfa being a deep feeder obtains a considerable portion of its mineral nutrients below the range of most other plants. When it has once established itself this is a means of increasing to some extent the phosphorus and potassium content of the upper soil stratum. Although when growing under conditions favorable for the development of the organisms which gather nitrogen from the air it increases the nitrogen supply of the soil, the fact should not be lost sight of that it draws heavily upon the mineral substances which are necessary for its growth. Phosphorus, potassium and calcium especially are removed in larger amount by an average crop of alfalfa than by any other farm crop.

If the crop is removed and no provision made for the return of the plant food assimilated by the plant, it is readily apparent that, although there is an increase in the nitrogen supply of the soil, there will be a rapid depletion of some of the other essential soil constituents. For the purpose of setting forth the differences in the plant food content of alfalfa and other farm crops, there is included in Table I an average of a large number of analyses of the several crops represented.

TABLE I. Composition of Alfalfa and other farm crops.[1]

Crop	Nitrogen	Phosphorus[2]	Potassium[3]	Calcium[4]
	Percent	Percent	Percent	Percent
Alfalfa hay	2.720	.2901	1.6600	1.5070
Timothy hay	0.841	.1308	1.3367	0.2281
Clover hay	2.167	.1829	1.1242	1.4293
Soybeans	5.430	.6270	1.8700	0.1860
Soybean straw	2.000	.0686	0.6810	1.0430
Wheat	1.975	.3486	0.3547	0.0357
Wheat straw	0.528	.0908	0.8304	0.1929
Oats	2.012	.4095	0.5789	0.0786
Oats straw	0.581	.0875	1.0947	0.3574
Corn	1.758	.2391	0.3402	0.0214
Corn stover	0.814	.0667	0.7795	0.3658
Corn cobs	0.500	.0261	0.6393	0.0571
Potatoes	0.340	.0700	0.4810	0.0210

[1]This table has been compiled from analyses made at this Station.
[2]To reduce phosphorus to phosphoric acid (P_2O_5) divide by .4366. Thus .2901÷.4366=.6944.
[3]To reduce potassium to potash (K_2O) divide by .83. Thus 1.6660÷.83=2.0000.
[4]To reduce calcium to lime (CaO) divide by .7143. Thus 1.5070÷.7143=2.1098. To reduce magnesium to magnesia (MgO) divide by .6.

DISTRIBUTION OF THE SEVERAL CONSTITUENTS

Table II, giving the composition of alfalfa seeds, leaves and stems, shows the distribution of the several constituents determined.

TABLE II. Composition of Alfalfa Seeds, Leaves and Stems.

	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulphur
	Percent	Percent	Percent	Percent	Percent	Percent
Alfalfa seed	5.87	.5170	0.9815	0.1880	.1542	.3494
Alfalfa leaves	3.72	.3780	2.8818	1.5200	.2974	.5519
Alfalfa stems	1.36	.2790	2.9721	0.5200	.1553	.1867

Phosphorus and nitrogen follow the same order in the case of the alfalfa plant that they do in most other cultivated plants, viz: that larger amounts of these two elements are present in the seeds than in the stems and leaves. When alfalfa is cut at the right stage for hay, the greater portions of the elements, with the exception of potassium, which have been assimilated by the plant during its growth are contained in the leaves.

The amount of potassium contained in the stems is slightly higher than that present in the leaves, and three times greater than the quantity found in the seeds. The largest percent of nitrogen and phosphorus being found in the seeds, it is true that a portion of the mineral constituents, especially phosphorus, will be removed from the soil by this part of the plant, but the quantity is relatively small as compared with that in the crop cut for hay. It is estimated that the normal yield of seed in the localities where it is produced is from four to eight bushels per acre. Basing a calculation upon the percentage composition, the amounts of nitrogen and phosphorus contained in an 8-bushel yield of seed and 6,000 pounds of hay are

28 pounds of nitrogen and an average of 2.5 pounds of phosphorus for the seed, and for the hay, 163 and 17 pounds, respectively, of nitrogen and phosphorus.

The leaves are the most important part of the alfalfa hay crop, since they contain the greater part of the mineral elements, as well as the bulk of the nutritive constituents for which the alfalfa plant is so highly valued for feeding purposes.

The decreased value of the crop which may occur through the loss of leaves due to careless handling in harvesting is in some instances considerable. From data obtained by the Agronomy Department of this Station, it is estimated that the leaves constitute 60 percent of the weight of the alfalfa plant when harvested for hay; hence, 3.72 percent nitrogen in the leaves means that approximately 80 percent of the protein, which is the most valuable of the nutritive constituents of the alfalfa plant, is contained in the leaves.

PLANT FOOD REMOVED PER ACRE

Table III on page 759 shows the amount of the more important elements removed in alfalfa per acre by the yields obtained under different conditions of soil treatment. The amount of nitrogen is larger than that of any other element contained. Most of this is undoubtedly supplied to the plant through its symbiotic relation with the micro-organisms contained in the soil.

Potassium, which is supposed to be one of the constituents of protoplasm and is an important factor in the formation of starch, is relatively abundant in the alfalfa plant. The quantity of this element is greater than that of any other of the mineral nutrients removed by a crop of alfalfa. This necessitates the supplying of available potassium in fertilizers if a sufficient quantity is not already present in the soil. This is pointed out very clearly by the increased yield produced by the application of a small amount of available potassium to the soil upon which the alfalfa crops were grown.

In some instances a single crop may remove more potassium than is supplied at the rate indicated in the tables showing the fertilizer treatment. The total amount of potassium added to plots receiving this element, from the time of the first seeding to 1911, was 88 pounds per acre, while 116 pounds per acre was the total amount removed by the first cutting from the plots fertilized with acid phosphate and potassium, on the section treated with 2,500 pounds of lime. The second cutting removed 54 pounds of this element and the third approximately 36 pounds, making a total of 206 pounds of potassium removed per acre from this particular plot during one year, as compared with 17.5 pounds added per year.

TABLE III: Showing the amount of several elements removed per acre by the yields of alfalfa indicated.

	Fertilizing elements per acre			Lime per acre	Yield	Amount removed per acre					
	Phosphorus	Potassium	Nitrogen			Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulphur
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
First cutting	Unfertilized			2,500	4,241	125 46	10 10	81.73	74.04	13.61	13.55
First cutting	Unfertilized			5,000	3,670	112.26	9 99	62 93	60.47	13.26	12 80
Second cutting	Unfertilized			2,500	1,877	44 93	3.61	29.70	22.31	6.63	6 93
Second cutting	Unfertilized			5,000	1,865	45 26	3.97	28 59	22.92	7 14	5.69
First cutting	45	..	..	2,500	5,219	163 88	17 82	119.83	73.53	12.44	15.63
First cutting	45	..	..	5,000	4,151	134.49	12.98	64.21	77.50	17.61	15.37
Second cutting	45	..	..	2,500	2,946	67.75	7 38	63 51	32.76	8.21	8.94
Second cutting	45	..	..	5,000	1,931	49 04	4.72	21.79	24.14	8.40	6.21
First cutting	45	25	..	2,500	5,724	163.71	17.83	116.03	86 92	17.52	17.06
First cutting	45	25	..	5,000	5,003	153 59	14.58	79.70	94.18	17.79	17.63
Second cutting	45	25	..	2,500	3,073	76 82	8.21	54.93	30 44	9.95	9.40
Second cutting	45	25	..	5,000	2,395	55.80	5.23	32.00	30 18	8.69	7.79
First cutting	45	25	12	2,500	5,135	153.02	14 96	96.63	83.03	16 11	17.32
First cutting	45	25	12	5,000	5,054	155.66	12.88	69.80	93.67	22.50	17.44
Second cutting	45	25	12	2,500	2,694	64.92	6.30	40.90	26.05	8.42	8.34
Second cutting	45	25	12	5,000	2,119	55.09	4.90	21.44	24.92	9.29	6.06
First cutting	45	..	12	2,500	4,840	147.62	12 59	83.21	74.23	16.10	16.55
First cutting	45	..	12	5,000	4,527	132.19	12.48	62.13	83.73	18.66	13.96
Second cutting	45	..	12	2,500	2,610	64.72	6.32	37.01	26.91	9 96	7.87
Second cutting	45	..	12	5,000	1,969	49 02	4.56	23.95	24.15	7.51	6.00
*First cutting	24	56	72	2,500	4,714	137.18	11.65	95.71	69 61	15.35	15.01
First cutting	24	56	72	5,000	4,251	133.48	11.46	62.93	74.49	17.66	13.79
*Second cutting	24	56	72	2,500	2,694	63.57	5.88	39.99	30 59	8.95	6 85
Second cutting	24	56	72	5,000	1,919	48.35	4.81	23 97	21 59	8.13	4.51

*From 16,000 pounds of stable manure.

Calcium is generally regarded as a soil amendment rather than a plant food, but where it is assimilated in the quantities shown by the analysis of the plant it is evident that a considerable supply is necessary as a plant food. Basic materials other than calcium oxide or carbonate might be applicable for neutralizing the acid condition of soils, but so far as the nutrition of leguminous plants is concerned, a supply of available calcium is just as necessary as either phosphorus or potassium. However, when basic calcium compounds are furnished in quantity sufficient for the needs of the soil the demands of the plant will more than be supplied.

In most plants magnesium is contained more abundantly in the seeds than in the leaves and stems. The reverse is found in alfalfa, since the analyses of mature plants show that equal quantities of this element are present in the stems and seeds, while the leaves contain a larger amount. The amount of magnesium assimilated indicates that this element is essential for plant growth, and also that where increased amounts are presented to the plant* it will assimilate a proportionally larger quantity of this element.

The results obtained show that calcium is removed from one acre of soil by a 3-ton crop of alfalfa hay at the rate of about 90 pounds, while the amount of magnesium removed is only about 20 pounds.

Sulphur, which is an invariable constituent of protein and is therefore necessary for the formation of all plant proteids, is present in relatively large quantities in alfalfa and other plants containing large amounts of protein. In most soils sulphur is more deficient than is phosphorus. The composition of rain-water collected at various localities shows that a considerable quantity of this element is carried to the soil by the rainfall. For cereal crops, the supply of sulphur in the soil, together with that added by the rain, is amply sufficient, but for heavy yields of leguminous plants rich in albuminoids, resource to other supplies would seem to be necessary. When acid phosphate is used as a carrier of phosphorus it also supplies sulphur; 100 pounds of 14 percent available acid phosphate (6 percent phosphorus) contains 11 pounds of sulphur in the form of calcium sulphate. The practice of using gypsum or calcium sulphate is not followed to the extent it was formerly. The remarkable stimulating effect produced on clover following its use was believed to be due to the liberating of plant food from insoluble substances by chemical action on the phosphorus compounds of iron and a double decomposition of potassium silicates. It is probable that the beneficial effects noticed where gypsum was used were due in part

* A magnesian lime was used in these experiments.

to the sulphur supplied. The increased yields obtained by the use of acid phosphate in the case of the alfalfa crop studied may be due partly to the sulphur carried by this fertilizing material. The results, however, do not indicate any increased amount of sulphur in the crop grown where acid phosphate containing calcium sulphate was used. A less quantity of phosphorus is removed than of sulphur, an average of approximately 25 pounds of this element being removed during a single season, as compared with 35 pounds of sulphur.

It is a mistaken idea, commonly practiced, that after the growth of alfalfa is well started, it requires no further attention as to fertilizing or manuring. The considerable quantities of the mineral elements removed by a fair yield of alfalfa indicate clearly that in the case of soil only fairly fertile the supply of these mineral elements contained in the soil will be exhausted to the point where one or more of them may become the limiting factor in the growth of this crop. The fertilizing constituents removed from the soil by 6,000 pounds of alfalfa hay, compared with the amounts removed by average Ohio yields of other farm crops, are shown in Table IV. The nitrogen in alfalfa and the other leguminous crops is not to be considered as being obtained from the soil.

TABLE IV. Pounds of Plant Food contained in Average yields per acre of Farm Crops.

Crop	Yield per acre	Nitrogen	Phosphorus	Potassium	Calcium	Crop Lbs.
Alfalfa hay... ...	Lbs. 6,000	163.20	17.41	99.65	90 43	6,000
Timothy hay.....	Lbs. 2,250	18.92	2.95	30.08	5.13	2,250
Clover hay	Lbs. 2,200	47 67	4.03	24.74	31.44	2,200
Soybeans	Bus. 20	65.16	7.51	22.42	2.23	1,200
Soybean straw	Lbs. 2 800	56.00	1.92	19.09	29.20	2,800
Wheat............	Bus. 13.21	15.66	2 76	2 81	.28	793
Wheat straw.....	Lbs. 1,414	7.46	1.28	11.74	2.73	1,414
Oats.............	Bus. 33 64	21.66	4 40	6.23	.84	1,076
Oat straw.........	Lbs. 1,508	8.76	1.32	16.51	5.39	1,508
Corn...	Bus. 36 61	36.04	4.90	6.97	.44	2,050
Corn stover........	Lbs. 1,738	14.15	1.16	13.55	6.35	1,738
Corn cobs...... ..	Lbs. 512	2.56	.13	3.27	.30	512
Potatoes..........	Bus. 150	30.60	6.29	43.33	1.93	9,000

EFFECT OF FERTILIZERS ON COMPOSITION OF CROP

The percents of the constituents determined in alfalfa of first and second cuttings from the several differently fertilized plots are shown in Tables V and VI. The addition of phosphorus has increased to some extent the amount of this element found in the plant. This increase is most pronounced where phosphorus has been applied alone or in combination with potassium, and where only 2,500 pounds of caustic lime has been used as compared with 5,000 pounds of lime.

TABLE V. Composition of first cutting of alfalfa.

Plot	Fertilizing elements per acre			Lime per acre	Yield per acre	Composition of hay					
	Phosphorus	Potassium	Nitrogen			Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulphur
No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent
0	Average unfertilized			2,500	4,241	2.96	.2382	1.9347	1.7481	.3209	.3200
2	45	..	..	2,500	5,219	3 14	.3415	2.2918	1.4095	2384	.2996
3	45	25	..	2,500	5,724	2.86	.3116	2 0273	1.5192	.3062	.2982
5	45	25	12	2,500	5,135	2.98	.2914	1.8825	1 6176	.3138	.3374
6	45	..	12	2,500	4,840	3 05	.2603	1.7196	1.5344	3324	.3421
8*	24	56	72	2,500	4,714	2 91	.2472	2.0306	1.4771	.3258	.3185
	Average fertilized			....	5,126	2 99	.2904	1 9903	1.5115	.3033	.3191
0	Average unfertilized			5,000	3,670	3.06	.2734	1.7250	1 6494	.3616	.3490
12	45	.	..	5,000	4,151	3 24	3128	1.5473	1.8669	.4243	.3703
13	45	25	..	5,000	5,003	3 07	.2913	1 5921	1 8815	.3554	.3525
15	45	25	12	5,000	5,054	3.08	2388	1.3812	1 8535	4451	.3449
16	45	..	12	5,000	4,527	2.92	.2758	1.3731	1 8506	.4123	3085
18*	24	56	72	5,000	4,251	3.14	.2698	1.4810	1.7524	.4155	.3246
	Average fertilized			.....	4,597	3.09	.2777	1.4749	1.8409	.4105	.3401

0 Average of the unfertilized plots.
* From 16,000 pounds of stable manure.

For the first cutting from the section of the plots treated with 2,500 pounds of caustic lime the average phosphorus content of the alfalfa from plots receiving phosphorus is .2904 percent against .2382 percent for the unfertilized plots. With 5,000 pounds of lime used, the results for the fertilized and unfertilized crops are .2777 and .2734 percent, respectively.

TABLE VI. Composition of second cutting of alfalfa.

Plot	Fertilizing elements per acre			Lime applied	Yield per acre	Composition of hay					
	Phosphorus	Potassium	Nitrogen			Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulphur
No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent
0	Average unfertilized			2,500	1,877	2 41	.1885	1.5794	1 2030	.3516	3046
2	45	..	..	2,500	2,946	2 30	2507	2.1565	1 1120	.2788	.3037
3	45	25	..	2,500	3,073	2.50	.2674	1.7890	0.9907	.3238	.3061
5	45	25	12	2,500	2,694	2.41	.2340	1.5183	0.9671	3127	.3099
6	45	..	12	2,500	2,610	2.48	.2423	1 4183	1 0311	.3817	.3016
8*	24	56	72	2,500	2,694	2.36	.2184	1.4844	1 1356	.3325	.2543
	Average fertilized			.....	2,803	2.41	.2425	1.6733	1.0473	.3259	.2951
0	Average unfertilized			5,000	1 865	2.43	.2106	1.5279	1.2390	.3868	.3033
12	45	..	..	5,000	1,931	2.54	.2447	1.1282	1.2502	.4352	.3219
13	45	25	..	5,000	2,395	2 33	.2184	1.3361	1.2603	.3631	.3257
15	45	25	12	5,000	2,119	2.60	.2316	1.0121	1.1761	.4386	.2862
16	45	..	12	5,000	1,969	2.49	.2316	1.2168	1.2267	.3817	.3051
18*	24	56	72	5,000	1 919	2.52	.2232	1.2491	1.1255	4232	.2351
	Average fertilized			.....	2 067	2.49	.2299	1.1884	1.2077	.4083	.2948

0 Average of the unfertilized plots.
* From 16,000 pounds of stable manure.

Making the same comparison for the second cutting, with 2,500 pounds of lime there is .2425 percent of phosphorus in the crop from the fertilized plots and only .1885 percent where no phosphorus was added to the soil. Increasing the supply of available phosphorus in the soil with the larger quantity of lime has, as in the case of the first cutting, increased the phosphorus content of the plant to a less extent than where there was a smaller application of lime; the average phosphorus content of the crop from the fertilized plots being .2299 percent and that of the unfertilized crop .2106 percent.

Where both phosphorus and nitrogen were applied to the soil the percentage of phosphorus contained in the plant is smaller than where phosphorus was added without nitrogen. The relative quantity of phosphorus found, however, is still greater than that in the crop grown on unfertilized soil.

The small amount of phosphorus added to the fertilized plots will increase the percentage of this constituent in the soil to a very slight extent. The difficulty of securing soil samples which will be representative, and the limitation of chemical methods, often render it exceedingly difficult to obtain from an analysis of the soil a measure of the small difference caused by the addition of phosphorus, as in the case of the soil upon which the alfalfa crops analyzed were grown. The results obtained for phosphorus show that the composition of the plant reflects with considerable exactness the supply of available phosphorus. The complexity of soil conditions which influence crop growth and the contravening influence of one element utilized by a plant over another are such that it is impossible to draw definite conclusions from results obtained from a study of one crop on a particular soil. Previous investigations, made at this Station, on cereal crops grown on different soils where the difference in the phosphorus content of the soil and crop were even more marked than the results here reported, bear out the assumption that the phosphorus assimilated by the plant is a measure of the supply of phosphorus available for its use.*

It will be observed from the yields which are given in Tables V and VI, that the crop grown on soil treated with phosphorus in acid phosphate, alone or in combination, has produced a larger yield and at the same time contains a higher percent of phosphorus than that grown on unfertilized or manured land.

Where the soil has been treated with 2,500 pounds of lime, the crop from the unfertilized plots, for both the first and second cuttings, contains more magnesium than the average crop grown on the fertilized plots, while with the larger amount of lime added, there is

* Bulletin 221—The composition of Wheat.

an increased percentage of magnesium in the alfalfa grown on the fertilized plots. The calcium content follows the same order as the magnesium, with the exception of the crop of the second cutting from the unfertilized plots treated with 5,000 pounds of lime.

The potassium content stands in opposite relation to the calcium and magnesium. On both fertilized and unfertilized soil the crop treated with the smaller amount of lime contains the larger amount of potassium.

The addition of potassium to the soil has increased the yield per acre but has not increased the proportion of this element found in the crop. It is of interest to note, in this connection, that with the smaller application of lime the largest amount of potassium is found in the crop grown on soil fertilized with phosphorus alone, Plot 2. The magnesium in the crop from this plot is lower than in any other instance where 2,500 pounds of lime was applied. This relation between the potassium content and that of calcium and magnesium, which is found to exist under different conditions, indicates that calcium and magnesium may be able, to some extent, to replace potassium within the plant, or to render the supply of potassium in the soil less available.

INFLUENCE OF QUANTITY OF LIME APPLIED TO THE SOIL

The lime used contained approximately 55 percent of calcium oxide and 40 percent of magnesium oxide. It will be observed that the yields of alfalfa were smaller in every instance where the larger amount of lime was added. This decrease, however, was apparently due to soil conditions. There were four contiguous blocks of land in the experiment, the rate of liming and comparative yields of which were as follows:

Block A,	2,500	pounds lime,	8,061	pounds	alfalfa.
" B,	5,000	" "	7,335	"	"
" C,	2,500	" "	6,193	"	"
" D,	3,500	" "	5,681	"	"

The samples analyzed were drawn from Blocks A and B. While the larger application of lime has affected the composition of the crop it is not apparent that it has influenced the yield per acre.

The increased supply of the calcium and magnesium in the soil is shown by the composition of the crop, these elements being present in the plant in larger quantities when double the amount was supplied. The analytical results, as arranged in Table VII, show that the amount of lime used has caused variations, not only in the content of calcium and magnesium, but has also effected the amounts of the other constituents present. The potassium content is always higher with the smaller application of lime and follows the same order that has been referred to under the effect of fertilizers, that a high percentage of potassium is always accompanied by a low percentage of the elements calcium and magnesium.

TABLE VII: Showing the effect of increase of lime on the composition of alfalfa.

	Fertilizer treatment			Lime added	Composition of hay					
	Phosphorus	Potassium	Nitrogen		Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulphur
	Lbs.	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent
First cutting	Unfertilized			2,500	2.96	.2382	1.9347	1.7481	3209	.3200
First cutting	Unfertilized			5,000	3.06	.2734	1.7250	1.6494	.3616	.3490
Second cutting	Unfertilized			2,500	2.41	.1885	1.5794	1.2030	3516	.3046
Second cutting	Unfertilized			5,000	2.43	.2106	1 5279	1.2390	.3868	.3033
First cutting	45	..	..	2,500	3.14	.3415	2.2918	1.4095	.2384	.2996
First cutting	45	..	..	5,000	3.24	.3128	1 5473	1.8669	.4243	.3703
Second cutting	45	..	..	2,500	2.30	2507	2.1565	1 1120	.2788	.3037
Second cutting	45	..	..	5,000	2.54	.2447	1 1282	1 2502	.4352	3219
First cutting	45	25	..	2,500	2.92	.3116	2.0273	1.5192	.3062	.2982
First cutting	45	25	..	5,000	3.07	.2913	1.5921	1.8815	.3554	3525
Second cutting	45	25	..	2,500	2.50	.2674	1.7890	.9907	3238	3061
Second cutting	45	25	..	5,000	2.33	.2184	1.3361	1.2603	3631	.3258
First cutting	45	25	12	2,500	2.98	.2914	1.8825	1.6176	.3138	3374
First cutting	45	25	12	5,000	2.54	.2388	1.3812	1.8535	4451	.3449
Second cutting	45	25	12	2,500	2.41	2340	1.5183	.9671	.3127	.3099
Second cutting	45	25	12	5 000	2.60	.2316	1.0121	1.1761	.4386	.2862
First cutting	45	..	12	2,500	3.05	.2603	1 7196	1.5344	.3324	.3421
First cutting	45	..	12	5,000	2 92	.2758	1.3731	1.8506	4123	.3085
Second cutting	45	..	12	2,500	2.48	.2423	1.4183	1.0311	.3817	.3016
Second cutting	45	..	12	5,000	2.49	.2316	1.2168	1.2267	.3817	3051
*First cutting	24	56	72	2,500	2.91	.2603	1 7196	1.5344	.3324	.3421
First cutting	24	56	72	5,000	3.14	.2698	1.4810	1 7524	.4155	.3246
*Second cutting	24	56	72	2,500	2 36	.2184	1.4844	1.1356	.3325	.2543
Second cutting	24	56	72	5,000	2.52	.2232	1.2491	1.1255	4232	.2351

*From 16,000 pounds of stable manure

The phosphorus contained is higher in the crop from the unfertilized plots treated with 5,000 pounds of lime, while on the fertilized plots, the higher percentage is usually associated with the smaller applications of lime. In the first cutting an increased amount of sulphur is present in the crop grown where the larger application of lime was made; in the second cutting the amount assimilated is the same for both quantities of lime applied.

VARIATION IN FIRST AND SECOND CUTTINGS OF ALFALFA

The variations in composition of the first and second cutting of alfalfa grown under like conditions, as far as soil is concerned, point out some interesting facts.

The yields obtained were always greater from the first cutting, and the percentages of nitrogen, calcium, phosphorus and potassium follow the yield. Undoubtedly more of these mineral elements found in greater amounts in the larger yields of the first cutting were available for this crop than for the one following.

While the total amount of potassium in the soil upon which the alfalfa was grown is large, the addition of a small amount of potassium chloride has increased the yield. The first crop may have reduced the amount of available potassium to such an extent that the second crop utilized a large amount of magnesium in place of potassium. This is indicated by the fact that while the amounts of the several constituents are higher in the crop of the first cutting, the percent of magnesium found is an exception to the order observed and is higher in the second cutting.

While the results obtained for sulphur are not uniformly higher in the first cutting for each differently fertilized plot, the average results for both the unfertilized and fertilized plots show an increased amount of this element in the crop of the first cutting.

A peculiar characteristic of the alfalfa plant in respect to the nitrogen content is noticed where the first, second and third cuttings have been analyzed. The nitrogen content is lower for the second cutting than for the first; the amount in the third cutting, however, is generally higher than in the second.

Whatever may be the causes which are responsible for the variation in composition of the alfalfa plant grown on differently treated soil, and between the first and second cuttings, it is evident that the increased percentage of the mineral constituents found is not due to a lack of development of the plant. It has frequently been observed that plants grown on unfertile soil contain more of some of the mineral constituents than those which have attained complete development on more productive soil. The direct relation between the increased yield and percents of constituents present, especially phosphorus and potassium, shows that the variations noted are not due to the condition just referred to.

AMOUNTS OF MINERAL ELEMENTS SOLUBLE IN WATER

The mineral as well as the food elements are loosely combined in the alfalfa plant and are therefore readily washed out by rain. The assertion has been made that rain amounting to from one-half to one inch will decrease the value of alfalfa hay 25 percent. It is not an uncommon occurrence to see hay, corn fodder and other crops exposed to the weather for a considerable length of time, before being stowed away in shelter. In some cases no protection is afforded from the time they are cut until fed to the stock. That there is a considerable loss in feeding value is very evident from the appearance of the crop. Chemical analyses of the water solution show that a large amount of the mineral and organic compounds are dissolved out of a crop after it has been dried. This is undoubtedly one of the chief causes of the luxuriant growth of aftermath obtained by allowing a crop to remain on the ground for some time after it has been cut; for the essential elements so dissolved will be in an available form to be reassimilated by the second growth. However, the loss of nutritive elements is not altogether due to the leaching and washing out of the water-soluble materials, but also to the loss of leaves during harvesting, especially in the case of alfalfa, which contains the largest proportion of the organic and mineral food elements in this part of the plant.

Table VIII gives the amounts of the several constituents soluble in distilled water. The results show that 90 percent of the potassium, 85 percent of the magnesium, 75 percent of the phosphorus, 50 percent of the nitrogen and sulphur and 40 percent of the calcium contained in the dried alfalfa plant were soluble in water.

An interesting fact in relation to the combination of calcium in the alfalfa plant is pointed out by the small amount of total calcium which is soluble in water. Theories advanced by numerous investigators are at variance as to the functions of calcium in plant nutrition. It is often regarded chiefly as important for the neutralization of oxalic acid and acid oxalates. The total amounts of calcium present in the first cutting of alfalfa in Plot 14 is 1.7130 percent and from Plot 20, 1.6176 percent, while the amounts soluble in water are .5625 and .5687 percent, leaving 1.0489 and 1.1505 percent undissolved by water. The oxalic acid present in these samples was determined and the amount found was sufficient to combine with only .52 and .47 percent of calcium. There would still remain .6305 and .5789 percent, or almost one-third, of the calcium in an insoluble combination other than oxalates in the plant. It is evident that the presence of calcium is essential for the formation of some of the organic compounds.

TABLE VIII. Showing the amounts of the several elements soluble in water.

	Fertilizer elements per acre			Lime per acre	Water soluble elements					
	Phosphorus	Potassium	Nitrogen		Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulphur
	Lbs.	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent
First cutting	Unfertilized			2,500	1.45	.1913	1.8301	.8078	.2463	.1565
First cutting	Unfertilized			5,000	1 54	.2194	1.6843	.9145	.3048	.1638
Second cutting	Unfertilized			2,500	1.02	.1281	1.4094	.4875	.2656	.1510
Second cutting	Unfertilized			5,000	1.05	.1384	1.2609	.5197	.3057	.1381
First cutting	45	..	..	2,500	1.25	.....	......	......	.....	.....
First cutting	45	..	..	5,000	1.61	.2686	1.2330	1.0437	.3582	.1757
Second cutting	45	..	..	2,500	1.01	.1740	1.9889	.4375	.2242	.1524
Second cutting	45	..	..	5,000	1.10	.1685	......	.....	.....	.....
First cutting	45	25	..	2,500	1.34	.2602	2.0073	.5937	.....	.1730
First cutting	45	25	..	5,000	1.50	.2519	1.4216	.9125	.2898	.1757
Second cutting	45	25	..	2,500	1.01	.2125	1.6182	.3500	.2187	.1524
Second cutting	45	25	..	5,000	0.95	.1490	1.1814	.5500	.....	.1757
First cutting	45	25	12	2,500	1.52	.2491	1.7359	.8250	.2693	.1798
First cutting	45	25	12	5,000	1.62	.2004	1.2797	1.1875	.3896	.1647
Second cutting	45	25	12	2,500	0.92	.1727	1.3216	.3313	.2173	.1277
Second cutting	45	25	12	5,000	1.06	.1795	0.8252	.4937	.3417	.1332
First cutting	45	..	12	2,500	1.45	.2043	......	.....	.....	.....
First cutting	45	..	12	5,000	1.52	.2018	1.1637	1.0562	.3527	.1386
Second cutting	45	..	12	2,500	0.97	.1710	......	.3500	.2802	.1469
Second cutting	45	..	12	5,000	1.04	.1530	1.0396	.5000	.....	.0974
*First cutting	24	56	72	2,500	1.46	.1962	1.9019	.7375	.2625	.1441
First cutting	24	56	72	5,000	1.52	.2060	1.2539	.8687	.2912	.1386
*Second cutting	24	56	72	2,500	1.09	.1445	1.3748	.4375	.2542	.1290
Second cutting	24	56	72	5,000	1.07	.1310	1.1604	.4125	.3062	.1441

*From 16,000 pounds of stable manure.

Almost all of the sulphur determined as water soluble was in the form of sulphates, chiefly potassium sulphate. Fifty percent of the total sulphur in the alfalfa plant may be considered as a constituent of the proteid bodies.

SEPARATION OF NITROGEN COMPOUNDS

The percent of total protein, as stated in connection with the composition of vegetable substances, includes besides the albuminoids or proteids which are of value for feeding purposes, other nitrogen containing substances. These are chiefly the amine compounds and the non-digestible protein bodies. The addition of fertilizers to the soil has not changed to any extent the total quantity of nitrogen or the proportion of it which is present either as amines or albuminoids.

Differences in the amounts of proteid and amine nitrogen, however, are observed in the first and second cuttings. The water-soluble nitrogen, which contains all the amine nitrogen and a portion of the protein bodies known as proteoses, albumin and globulin, is increased by the larger addition of lime in the first cutting. In the crop of the second cutting no increase is noticed in this respect.

The greater amount of water-soluble nitrogen found in the crop of the first cutting grown on soil treated with 5,000 pounds of lime is largely due to the increased accumulation of amine nitrogen in the plant. There is a greater percentage of the total nitrogen combined as proteid nitrogen in the crop of the second cutting where the yields were the smallest.

The pepsin-soluble protein nitrogen found in the crop of the first cutting is somewhat greater where the increased application of lime was made. This amount represents the proteid which is of most importance for feeding purposes.

The data show that there is a tendency for the pepsin-soluble nitrogen to be higher in the first cutting than in the second.

Table IX gives the results obtained for the nitrogen separations made.

TABLE IX. Showing the nitrogen separations.

	Fertilizing elements per acre			Lime per acre	Forms of nitrogen					Protein nitrogen percent of total
	Phosphorus	Potassium	Nitrogen		Total	Amine	Protein	Water-soluble protein	Pepsin-insoluble	
	Lbs.	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent
First cutting	Unfertilized			2,500	2.96	0.95	2.01	.50	1.262	67.91
First cutting	Unfertilized			5,000	3.06	1.02	2.04	.51	1.253	66.66
Second cutting	Unfertilized			2,500	2.41	0.55	1.86	.47	1.080	77.18
Second cutting	Unfertilized			5,000	2.43	0.61	1.82	.44	1.040	74.90
First cutting	45	..	..	2,500	3.14	....	....	....	1.495	.....
First cutting	45	..	..	5,000	3.24	1.17	2.07	.44	1.210	63.89
Second cutting	45	..	..	2,500	2.30	0.49	1.81	.52	1.020	78.70
Second cutting	45	..	..	5,000	2.54	0.64	1.90	.45	1.130	74.80
First cutting	45	25	..	2,500	2.86	0.86	2.00	.48	1.170	69.93
First cutting	45	25	..	5,000	3.07	1.02	2.05	.48	1.160	66.77
Second cutting	45	25	..	2,500	2.50	0.57	1.93	.44	1.030	77.20
Second cutting	45	25	..	5,000	2.33	0.51	1.82	.44	0.985	78.11
First cutting	45	25	12	2,500	2.98	1.04	1.94	.48	1.170	65.10
First cutting	45	25	12	5,000	3.08	1.10	1.98	.52	1.140	64.28
Second cutting	45	25	12	2,500	2.41	0.50	1.91	.42	0.950	79.25
Second cutting	45	25	12	5,000	2.60	0.58	2.02	.48	1.035	77.69
First cutting	45	..	12	2,500	3.05	0.84	2.21	.61	1.230	72.46
First cutting	45	..	12	5,000	2.92	1.02	1.90	.50	1.120	65.07
Second cutting	45	..	12	2,500	2.48	0.54	1.94	.43	1.050	78.23
Second cutting	45	..	12	5,000	2.33	0.51	1.82	.44	0.985	78.11
*First cutting	24	56	72	2,500	2.91	1.02	1.89	.44	1.155	64.95
First cutting	24	56	72	5,000	3.14	1.06	2.08	.46	1.270	66.24
*Second cutting	24	56	72	2,500	2.36	0.57	1.79	.52	1.000	75.85
Second cutting	24	56	72	5,000	2.52	0.57	1.95	.50	1.080	77.38

*From 16,000 pounds of stable manure.

TABLE X: Showing phosphorus separations.

	Fertilizing elements per acre			Lime per acre	Forms of phosphorus					
	Phosphorus	Potassium	Nitrogen		Total	Organic	Inorganic	Organic percent of total	Water soluble percent of total	Pepsin insoluble
	Lbs.	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent
First cutting	Unfertilized			2,500	.2382	.1180	.1201	49.54	80 32	.0560
First cutting	Unfertilized			5,000	.2734	.1267	.1466	46.35	80.22	.0559
Second cutting	Unfertilized			2,500	.1885	.1190	.0694	63 13	73.24	.0455
Second cutting	Unfertilized			5,000	.2106	.1270	.0836	60.31	65.71	.0519
First cutting	45	..	..	2,500	.3415	.1494	1921	43.75	83.50	.0947
First cutting	45	..	..	5,000	.3128	.1513	.1615	48.37	86.48	.0656
Second cutting	45	..	..	2,500	.2507	.1183	.1324	47.19	79.47	.0550
Second cutting	45	..	..	5,000	.2447	.1529	.0919	62 49	68.22	.0480
First cutting	45	25	..	2,500	.3116	.1473	.1643	47.28	85.48	.0619
First cutting	45	25	..	5,000	.2913	.1295	.1618	44.46	83.92	.0598
Second cutting	45	25	..	2,500	.2674	.1402	.1272	52 43	73.80	.0473
Second cutting	45	25	..	5,000	.2184	.1265	.0919	57.92	77.50	.0529
First cutting	45	25	12	2,500	.2914	.1407	.1507	48.28	78.53	.0640
First cutting	45	25	12	5,000	.2388	.1169	.1219	48 96	73.17	.0515
Second cutting	45	25	12	2,500	.2340	.1329	.1011	56.80	70.58	.0445
Second cutting	45	25	12	5,000	.2316	.1191	.1125	51.43	77.50	.0529
First cutting	45	..	12	2,500	.2603	.1158	.1445	44.49	.....	.0689
First cutting	45	..	12	5,000	.2758	.1243	.1515	45.07	85.87	.0508
Second cutting	45	..	12	2,500	.2423	.1456	.0967	60 10	69.40	.0506
Second cutting	45	..	12	5,000	.2316	.1344	.0972	58.03	79.46	.0522
*First cutting	24	56	72	2,500	.2472	.1096	.1376	44.34	.....	.0662
First cutting	24	56	72	5,000	.2698	.1248	.1450	46.26	.....	.0522
*Second cutting	24	56	72	2,500	.2184	.1174	.1010	53.75	.....	.0410
Second cutting	24	56	72	5,000	.2232	.1446	.0786	64.79	.....	.0543

*From 16,000 pounds of stable manure.

PHOSPHORUS SEPARATIONS

Table X on page 771 gives the results obtained for the several phosphorus separations made. From 43 to 63 percent of the total phosphorus present in the alfalfa plant is combined as organic phosphorus. There is in each instance, for every condition of fertilization, a greater proportion of the total phosphorus present as organic phosphorus in the second cutting, while the amount of total phosphorus is always larger in the first cutting. The water-soluble phosphorus, which includes practically all the inorganic phosphorus and a considerable portion of that in organic combination, stands in the same order as the total phosphorus and is present in greater amounts in the crop of the first cutting. The quantities of pepsin-insoluble phosphorus which is combined with nitrogen as a highly insoluble compound, and would be of doubtful value from a nutrition standpoint, amounts to about 20 percent of the total phosphorus.

SUMMARY

Alfalfa cut in bloom contains the largest amounts of the more valuable plant foods and nutritive constituents in the leaves. About 80 percent of the protein in the plant is present in the leaves.

Considerable care should be exercised in harvesting this crop, since under the most favorable circumstances the loss of leaves may amount to about 15 percent of the total crop.

Mineral plant food constituents of the soil are removed in greater quantities by alfalfa than by any other farm crop. A 6,000-pound yield of alfalfa hay contains 163 pounds of nitrogen, 17 pounds of phosphorus, 99 pounds of potassium and 90 pounds of calcium.

The phosphorus supply of the soil, as increased by the addition of acid phosphate, is reflected by the phosphorus content of the crop, which follows the same order as the yields obtained.

When the fertilizer used contained both phosphorus and nitrogen, the increase in the amount of phosphorus over that found in the crop from unfertilized soil is not as great as where phosphorus without nitrogen was applied.

The potassium content stands in opposite relation to the calcium and magnesium. The crop containing the largest amount of magnesium has assimilated the smallest quantity of potassium.

Increasing the amount of calcium and magnesium in the soil by the addition of lime containing 55 percent calcium oxide and 40 percent magnesium oxide has caused a greater proportion of calcium and magnesium to be absorbed by the plant. Where this is the case the yield has been decreased.

The percentages of nitrogen, phosphorus, potassium and calcium are higher in the first cutting of alfalfa, where the yields were larger, than in the second cutting. The large amount of these elements removed indicates a rapid depletion of the essential mineral constituents from the soil.

The nitrogen content of alfalfa is less in the second cutting than in the first and increases in the third cutting.

Rain removes a considerable portion of the mineral and food elements which are not securely combined in the alfalfa plant. Results obtained by treating dried alfalfa with water show that 50 percent of the nitrogen and 75 percent of the phosphorus were dissolved.

More of the total nitrogen is combined as protein in the second cutting than in the first. Approximately 66 percent of the nitrogen in the first cutting is protein and 77 percent in the second cutting.

The amine nitrogen in the crop of the first cutting is increased by the larger application of lime.

About 50 percent of the total phosphorus of the alfalfa plant exists in the form of organic phosphorus.

While the amount of total phosphorus is greater in the first cutting, a greater proportion of it is combined as organic phosphorus in the second cutting.