THE MINERAL NUTRIENTS IN BLUE-GRASS

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THE MINERAL NUTRIENTS IN BLUE-GRASS

BY E. B. FORBES, A. C. WHITTIER, AND R. C. COLLISON.

Grass and exercise are usually considered essential for the normal development of bone and muscle in live-stock; but not all grass will grow sound bone. In all extensive countries, including the United States, where live-stock raising is generally followed, there are regions where grazing animals suffer from malnutrition of the bones. The commonest form of this disease responds readily to treatment with bone-flour and other preparations containing calcium and phosphorus, and is invariably associated with abnormal composition of the range or pasture grass.

These facts are established. At the same time, however, there is a prevalent idea in the United States that animals generally get as much mineral matter in the food as they need, especially if they have access to pasture grass, and with this sweeping assumption the subject is usually dismissed by farmers and by teachers of agriculture as outside the field of practical interests.

With an idea that this attitude may have led us to overlook a somewhat important matter, the authors have examined samples of blue-grass selected from a number of localities in the various distinctive soil areas of this State, having in mind especially food-values rather than fertility considerations.

While the mineral content of vegetable crops is without doubt the resultant of a considerable number of varying factors, the most important of these is the composition of the soil. If a certain type of soil, or method of treatment, produces blue-grass of a certain corresponding composition, it is important that we demonstrate the facts, and point out their probable bearing on stock raising. In a state as large as Ohio, and containing as great a variety of soil types, there can hardly fail to be an interesting variation in the composition of blue-grass from different regions, for it is a well-known principle of physiology that plants have no selective capacity with reference to minerals in solution in the soil water.

While it seems unlikely that these variations cause acute or immediately perceptible effects on animals in Ohio, it seems entirely probable that in the course of the lifetime of animals they do cause, through a gradual molding of the growth, differences of considerable practical importance affecting not only the animals themselves, but also, indirectly, the life-work of stock-breeders and the prosperity and history of communities.

One usually builds up a live-stock breeding establishment but once in a lifetime, and if the composition of the soil upon which one chances to locate, and the treatment accorded the grass lands, are to enter largely into the determination of the measure of one's success in his life-work, these are too important matters to be ignored or to be left to chance.

In such a state as Ohio, where the use of commercial fertilizers is both general and profitable, it is also important that we observe what effects, if any, applications of fertilizers may have on the composition of the blue-grass; for if a profitable farm practice can overcome the effects, on the composition of blue-grass, of a natural deficiency of the soil, then the measure of our independence is very greatly increased.

In order that deficiencies in the mineral constituents of pasture grass should have a practical bearing on stock raising, it is necessary either (1) that the mineral nutrients be insufficient to sustain normal growth or milk production, with an animal subsisting upon pasture alone, or else (2) that the mineral constituents, while sufficient if an animal eats grass alone, should be insufficient to make good the deficiencies of the remainder of a mixed ration.

Our knowledge as to the mineral requirements of animals is slight. Such definite figures as have been published, rest for the most part on imperfectly established assumptions, and the indications from which we must approximate the truth do not warrant detailed and conclusive assertions. The following general observations may be made, however, with considerable assurance that they are true.

Calcium and phosphorus are important elements in the rations of milk-giving and of growing animals. The greatest need of growing animals for mineral nutrients is for the growth of the skeleton, and the quality of the bones of live-stock enters largely into the determination of their usefulness, especially in the case of horses.

Pasture grass varies greatly, according to soil and season, in those mineral constituents which contribute to the growth of bone. Under some circumstances of soil and climate, stock-raising is quite impossible because of failure of the forage to support growth of the skeleton, unless calcium and phosphorus be provided in some supplement.

The most famous horse-breeding center of the United States is in a region of limestone soils and luxuriant blue-grass, which our analyses show to be unusually rich in bone-food. It seems quite likely that these rich limestone soils enter into the determination of the success of stock-raising in such regions, through their effect on the composition of the pasture grass.

The method of this investigation is of necessity imperfect, in that factors other than the composition of the soil affect the composition of the grass. This fact is borne in mind, however, in the interpretation of the analyses.

Among the circumstances which tend to limit the value of these figures are the facts that it is impossible to collect all of the samples under the same conditions (1) as to leaching by rainfall, (2) as to sunlight and soil-moisture present during growth, and (3) as to closeness of previous pasturing. Still it is possible to establish some facts of importance.

The samples of grass used in this study were all taken as nearly as possible at the same stage of growth, that is, when first coming into bloom.

In order to eliminate, as far as practicable, seasonal variations, the analyses are grouped into tables according to the year in which the samples were taken.

On account of the importance of phosphorus in the growth of animals, our attention is naturally directed toward the content of the grass in this element, and especially to the chemical condition in which it is present. The uses which organic and inorganic phosphorus serve in the animal body appear to be sharply differentiated, the latter contributing to the growth of bone only, while some organic phosphorus compounds are useful, not only in the development of the bones, but also in the growth of muscles, nerve tissues, and all other parts of the animal body.

The first samples were taken in 1908, and the analyses appear in Table I, page 42.

TABLE I—ANALYSES OF BLUE-GRASS (*Poa pratensis*)

1908—Dry Matter Basis—Percent

No.	Ash	Nitrogen	Calcium	Potassium	Phosphorus	Source of Sample
1	5 25	1 59	.336	1 41	.212	Wooster, O Station farm.
2	6.01	1 99	.207	1 88	.213	Strongsville, O. Substation farm
3	6 09	1 69	.223	2 08	.259	Germantown, O. Substation farm.
4	5 28	1 63	.258	1.81	.213	Carpenter, O Substation farm. Bottom land.
5	5 57	1 89	.244	2 14	.169	Carpenter, O. Substation farm High land
6	6 14	1 76	.260	2.21	.307	Lexington, Ky. Exp. Station farm.

These first analyses show us (1) that there is marked variation in the mineral constituents of grass grown in different localities in Ohio; (2) that the phosphorus content of a sample of blue-grass from Lexington, Ky., was greater than the phosphorus content of the other samples; and (3) that the calcium content of a sample of grass from the Station farm at Wooster was higher than any other. Inquiry established the fact that this last grass had been twice fertilized with a complete fertilizer containing calcium.

TABLE II—ANALYSES OF BLUE-GRASS (*Poa pratensis*)

1909—Dry Matter Basis—Percent

No	Ash	Nitrogen	Calcium	Potassium	Phosphorus	Source of Sample
1	6.78	1.96	.288	2.57	.317	Hudson, O. W. R. Chamberlain.
2	6.54	1.59	.246	2.05	279	Zanesville, O.
3	8.66	2.09	.240	2.85	349	Boardman Center, Mahoning Co.
4	5.94	1.78	.185	1.80	.177	Strongsville, O. Substation farm.
5	6.78	1.96	.288	2.57	.317	Bedford O.
6	6.39	2 11	.307	2.30	.238	Chandlersville, O. Chas. Mc.Intire's farm.
7	6.07	1.74	.250	1.93	.202	Carpenter, O. Substation farm.
8	6.74	1.63	.367	2.04	.246	Cumberland, O. C. T. Bay's farm.
9	8.32	1.76	.424	2.18	.286	Cumberland, O. C. T. Bay's farm.
10	6.77	1.42	.179	1 90	.251	Findlay, C
11	6.09	2.13	.242	2.43	.246	Tacoma, O. L. P. Bailey's farm

Another set of samples was collected in 1909. The analyses are reported in Table II, page 42.

In these the ash was found to vary between 5.94 percent and 8.66 percent; the nitrogen between 1.42 and 2.13 percent; the calcium between .179 and .424 percent; the potassium between 1.80 and 2.85 percent; and the phosphorus between .177 and .349 percent.

That the mineral constituents of blue-grass in Ohio should vary as these figures indicate, is a matter of much interest, and one which can hardly fail to be of practical significance.

In order to learn the extent to which the mineral constituents of blue-grass can be affected by the use of fertilizers, an experiment was conducted in plots staked out on the Station lawn.

One plot was fertilized with sodium phosphate, another with potassium chloride, a third with lime (calcium oxide), each at the rate of 400 pounds per acre; a fourth plot was fertilized with a mixture of 400 pounds each of the three above-mentioned compounds, and three intervening plots were left unfertilized. The fertilizers were applied, a part of each at a time, on July 11 and October 6, 1908, and on March 30, 1909; and the grass samples for analysis were collected on June 10, 1909.

TABLE III—ANALYSES OF BLUE-GRASS (*Poa pratensis*)

1909—Dry Matter Basis—Percent.

No.	Ash	Nitrogen	Calcium	Potassium	Phosphorus	Inorganic phosphorus	Organic phosphorus	Source of Sample
1	5.48	1.49	.230	1.83	.277	.176	.101	Wooster, O. Station lawn. Fertilized with sodium phosphate.
2	5.08	1.52	.247	1.58	.235	.135	.100	Wooster, O Station lawn. No fertilizer.
3	5.47	1.50	.222	1.86	.265	.138	.127	Wooster, O. Station lawn. Fertilized with potassium chloride.
4	5 01	1.46	.311	1.63	.236	.130	.106	Wooster, O. Station lawn. Fertilized with lime (calcium oxide).
5	6 16	1.48	.250	1.82	.264	.161	.103	Fertilized with sodium phosphate, potassium chloride and lime (calcium oxide).

The analyses set forth in Table III, page 43, show (1) that the grass fertilized with sodium phosphate contained more phosphorus than any other; (2) that the grass fertilized with potassium chloride contained more potassium than any other; (3) that the grass fertilized with lime contained more calcium than any other; (4) that the grass fertilized with a mixture of the three compounds contained more ash than any other grass; (5) that the excess of phosphorus in the grass fertilized with sodium phosphate over that present in the unfertilized grass was all in an inorganic condition; that is, the addition of sodium phosphate to the soil did not increase the percentage of phosphorus-containing proteins in the blue-grass; (6) that the use of the phosphate as a fertilizer appeared to increase the potassium in the grass, and, conversely, the use of the potassium salt as a fertilizer increased the phosphorus in the grass; (7) that the use of lime was without noticeable effect on either the potassium or the phosphorus in the grass; and (8) that the addition of potassium chloride to the soil increased to a marked extent the organic phosphorus of the grass, while sodium phosphate and lime were without effect on this constituent.

The fact that potassium increased the organic phosphorus only indicates that it did not liberate phosphorus in the soil, but produced the increase of both total and organic phosphorus by its action within the plant. It would seem that potassium is necessary to the formation of organic phosphorus in the plant, and that as phosphates are withdrawn from solution in the sap of the plant by synthesis of the phosphorus into organic phosphorus compounds, its place is taken by more inorganic phosphates from the soil water, and thus both total and organic phosphorus in the plant are increased by the use of potassium chloride as a fertilizer, without increase in the inorganic phosphorus. It seems likely that nitrogen was the limiting factor in the growth of this grass and this fact may have left the grass without means of expression of the usual effects of some of the fertilizers applied. The test will be repeated in duplicate with nitrate added to one of the series of plots.

The last set of blue-grass samples was taken in June, 1910, twenty from various localities in Ohio, and four others, for comparison, from Lexington, Ky

The analyses in Table IV, page 45, are grouped, as indicated by the cross-rulings, according to the geological formation at the points where the samples were collected. A general geological survey, however, appears to be inadequate to our purpose, for the soils are often unrelated to the underlying rocks, and variations in the soil of adjoining fields appear to affect the composition of the grass to as great an extent as do the soils of different geological history.

In this table the ash* varies from 4.80 percent to 8.23 percent. Nitrogen is about as variable, and the range in these figures is from 1.38 to 2.41 percent. This variation is due principally to variations in the proportion of leaf to stem. This matter is largely influenced by the conditions of growth and pasturage. Hence, for our purpose, these nitrogen figures have no especial significance.

*In determining ash, we first ignite very carefully at low heat to crude ash, which is weighed. The crude ash is then leached with dilute hydrochloric acid, and washed first with hot water and then with alcohol, the leachings being rejected. The residue is then dried and weighed. This residue is then ignited, and the loss on ignition is subtracted from the weight of crude ash to give the weight of pure ash.

Calcium varies between .135 percent on a low, wet, clay soil and .344 percent on a fertile limestone upland. The calcium content is a matter of especial interest to stockmen, since calcium is much the most abundant mineral in the animal body, and is more likely than any other to be lacking in our foods for stock, especially in grain

Animals generally, even suckling young, seem to be able to use to advantage more calcium than the food usually contains.

TABLE IV—ANALYSES OF BLUE-GRASS (*Poa pratensis*)

1910—Dry Matter Basis—Percent.

No	Ash	Nitrogen	Calcium	Potassium	Phosphorus	Inorganic phosphorus	Organic phosphorus	Source of Sample
1	6 77	1 94	265	2 37	306	176	130	Carpenter Substation. Virgin clay soil, hill top; heavily fertilized with sheep droppings; stand good; rain four days before.
2	6 10	1 88	268	1 98	256	.124	132	Carpenter Substation. Virgin clay soil, valley; sheep pasture; growth short; rain four days before.
3	5 28	1 40	240	1 74	.297	154	143	Carpenter Substation. Clay hill, recently reseeded; complete fertilizer; growth scant; rain four days before.
4	5 73	1 53	218	2 07	.191	106	088	Byesville, O. Wm. Mallern's farm. Red clay, virgin sod; not pastured; rain preceding day.
5	7 03	1 71	.212	2.13	274	156	118	Wooster, O. Bell Bros. farm. Waverly clay creek bottom; old pasture; richly manured by horses and cattle; rain three days before.
6	5 73	1 69	254	1 86	247	183	064	Wooster, O. L. M. Reed's farm. Yazoo clay; virgin woodland pasture; thin growth; rain three days before.
7	5 40	1 67	229	1 75	284	167	117	Wooster, O. D. P. Yoder's farm. Miami clay; old pasture; grass thin and short; rain three days before.
8	6.71	2 01	222	2 61	283	172	111	Wooster, O. Neil McCoy's farm. Volusia silt loam; virgin sod; rank growth; rain three days before.
9	4 98	1 53	135	1 72	.191	.098	.093	Strongsville Substation. Stiff clay, low and wet, virgin soil; pasture; growth scattering; rain four days before.
10	7 00	1 91	344	2 02	367	.231	.136	Lexington, Ky. Milton Young estate. Virgin limestone soil; high ground; horse pasture; grass short; rain preceding day.
11	8 04	2 41	.288	2.84	.403	.267	.136	Lexington, Ky. Exp. Station farm. Limestone soil; old pasture east of dairy barn; rich with cow droppings; rain preceding day.
12	5.75	1 59	.246	1.74	.337	.228	.109	Lexington, Ky. Exp. Station farm. Limestone soil; upland; old pasture east of test plots; good growth; not much pastured; rain preceding day.
13	7 52	1.74	.303	2 00	.384	.230	.154	Lexington, Ky. Exp. Station farm. Upland limestone soil; four-year-old pasture; preceding crop tobacco; grass thin; rain preceding day.

TABLE IV CONCLUDED—ANALYSES OF BLUE-GRASS (*Poa pratensis*)

1910—Dry Matter Basis—Percent

No	Ash	Nitrogen	Calcium	Potassium	Phosphorus	Inorganic phosphorus	Organic phosphorus	Source of Sample
14	6.92	1.77	.259	2.03	.305	.174	.131	Harpster, O. C. H. Lewis's farm. Dark rich loam, old sheep pasture, pastured closely, rain preceding day
15	7.34	1.87	.250	2.35	.322	.197	.125	Harpster, O. Farm adjoining that of C. H. Lewis. Virgin pasture, dark loam, heavily manured, rank growth, rain preceding day
16	8.23	1.65	.321	1.96	.317			Findlay, O. Near Substation farm. Limestone close to surface, pasture 20 years old, good growth, rain two days before
17	6.90	1.64	.278	1.90	.283			Arlington, O. Farm of Godfrey Crates. Soil dark loam, 10 year old pasture, grass thin and poor, rain two days previous
18	7.54	1.73	.234	1.76	.245			Washington C. H., Ohio. Farm of R. Taylor, dark loam, old dairy pasture, grass thin and poor, rain three days before
19	5.32	1.56	.247	1.84	.280	.184	.096	Vermillion, O. H. R. Fairchild's farm. Low wet stiff clay, woodland pasture; growth scanty, rain three days before
20	5.37	1.38	.228	1.79	.288			Chillicothe, O. G. P. Lauer's farm. Clay loam, Scioto Valley old bottom pasture, good growth, rain four days before
21	4.80	1.54	.191	1.51	.164	.064	.100	Chillicothe, O. Water works land. Virgin clay hill top, not pastured, rain four days before
22	6.37	1.85	.255	2.03	.288			Milledgeville, O. Ford Hardware Co. farm. Dark, rich loam pasture 35 years old, grass thin, rain three days before.
23	5.90	1.99	.253	2.17	.270			Tacoma, O. L. P. Bailey's farm. Soil clay, on sandstone, very old dairy pasture, good growth, rain on day preceding
24	5.70	1.45	.212	1.77	.193			Germantown, O. Swartzel farm. Clay loam, virgin woodland, rain two days before

Potassium varies in these figures between 1.51 and 2.84 percent, but this variation is not practically significant because potassium is probably present in sufficient amount in all ordinary rations.

Considering these figures in a general way, the phosphorus is usually slightly in excess of the calcium, though the reverse is sometimes true, and the potassium is usually present in 8 to 10 times these quantities.

Those samples which were lowest in organic phosphorus (Nos. 4, 6, 9, 19, 21 and 24) were also low in total phosphorus. No. 4 was from an infertile clay hillside. Nos. 6 and 24 were from clay soil in woodland pastures. Nos. 9 and 19 were from infertile clays in low, wet situations, and No. 21 was from a poor, thin, clay hilltop.

Those samples which were richest in phosphorus were from pastures which were heavily fertilized by the excreta of animals grazing upon them. In one such pasture the grass contained .403 percent of phosphorus, on a dry-matter basis, while on a thin clay hilltop the grass contained only .164 percent of phosphorus.

The organic phosphorus content of these grasses was generally highest where the total phosphorus was highest, and where the grass had been heavily fertilized. The next to the highest figure of all for organic phosphorus accompanies a medium total phosphorus content in a field of grass which had been twice fertilized with a complete commercial fertilizer. (Sample No. 3). The highest figure for organic phosphorus was on sample No. 13 from Lexington, Ky., from a field of blue-grass following tobacco. In this table the samples whose total phosphorus contents are below .25 percent average .086 percent organic phosphorus, those from .250 to .300 percent average .120 percent organic phosphorus, while those above .300 percent total phosphorus average .128 percent organic phosphorus.

Thus we may conclude that the organic phosphorus may be increased by manuring and the use of complete fertilizers, but not to so great an extent as the inorganic phosphorus. It appears, however, from our fertilizer experiment (Table III, p. 43) that fertilization with a salt of phosphoric acid alone does not necessarily increase the organic phosphorus of the grass, though it would probably do so if phosphorus were the limiting factor in the growth of the grass. The fact that on our Station lawn a heavy application of sodium phosphate increased only the inorganic, but not the organic phosphorus, probably indicates that in this particular piece of ground, in its present condition, phosphorus is not the limiting factor in the growth of blue-grass.

The first three samples in this table are from the Carpenter Substation farm. They are all much above the average in calcium and phosphorus. The first two samples are from sheep pasture, one on a hilltop and the other in a valley. The third sample is from a hill field which was fertilized with a complete fertilizer. These three samples stand in the same relation to each other in richness in the various constituents with considerable regularity, except in the case of phosphorus, both organic and inorganic.

Sample No. 4, from Byesville, was taken from a red clay soil and is not rich in any constituent, but is least poor, as might have been expected, in potassium.

Samples 5, 6, 7, and 8 are from different soil types near Wooster. There appears to be no such regularity in the composition of these samples from various soil types, as there was in the composition of the three samples from the Carpenter Substation farm.

Among these Wooster samples the phosphorus was lowest in the grass from L. M. Reed's woods pasture, and the phosphorus in this sample was also less largely organic than in any other sample.

Sample 8, from Neil McCoy's farm, was especially rich in potassium. This was grown on Volusia silt loam.

Sample 9, from the Strongsville Substation farm, was exceedingly low in ash, lower than any other sample in this table, except No. 21, which was from a very poor soil at Chillicothe. The calcium and phosphorus in these two samples is also very low, but the organic phosphorus was much more nearly normal than the inorganic.

In marked contrast to these two poor samples are four from Lexington, Ky., Nos. 10, 11, 12 and 13. The most conspicuous difference between these samples and others is in the phosphorus content, especially the inorganic phosphorus. No. 12 was not so rich in any constituent as were the other three. The pasture furnishing this sample had received the least manure. No. 11 was exceedingly rich in phosphorus, potassium and nitrogen, and was very heavily manured with cow droppings.

Samples No. 14 and 15 are from Harpster, 16 from Findlay, 17 from Arlington, and 18 from Washington C. H. All these are in the Monroe limestone region, but since this is a glaciated district, the relation between the soil and the underlying rocks in any particular place is not positively known. The samples from Harpster and Findlay were from good pastures, very much better than those at Arlington and Washington C. H., from which samples were taken, and the grass is correspondingly richer in the mineral nutrients.

Sample 19, from Vermillion, is from a low, wet, woods pasture on a stiff clay soil. This grass was not rich in any of the mineral nutrients. It was poorer in organic phosphorus than in other constituents.

Samples 20 and 21 were from Chillicothe. The former was from a rich bottom-land pasture and the latter was from a poor hilltop. The richer soil produced the richer grass—richer in all of the mineral nutrients.

Sample 22, from Milledgeville, was of good average quality and not remarkable in any way, and the same is true of Sample 23 from Tacoma.

Sample 24, from the Swartzel farm, at Germantown, was below the average in all constituents, especially in phosphorus.

CANADIAN BLUE-GRASS COMPARED WITH KENTUCKY BLUE-GRASS

The esteem in which Canadian, or flat-stemmed, blue-grass is held varies greatly with the locality in which it is grown. Where Kentucky blue-grass grows well the Canadian blue-grass is scorned as a pest, while in regions which are not blessed with the better variety the Canadian blue-grass is highly prized.

The Canadian blue-grass is comparatively woody, and we find this fact reflected in a lower nitrogen and higher potassium content. Assuming our average figures as set forth in the last two lines of the table to represent the facts of the case, the Kentucky blue-grass is the richer in nitrogen, calcium and phosphorus. It is more palatable, and ought to be a better food. (Table V, p. 49).

TABLE V—CANADIAN BLUE-GRASS (*Poa compressa*) COMPARED WITH KENTUCKY BLUE-GRASS

Dry Matter Basis—Percent

No.	Ash	Nitrogen	Calcium	Potassium	Phosphorus	Source of Sample
1	5.97	1.78	.236	2.53	.176	Tacoma, O. L P Bailey's farm Dark, sandy loam, clay subsoil. Canadian blue-grass.
2	5.44	1.12	.182	1.99	.143	Carpenter, O Substation farm. Canadian blue-grass
3	6.57	1.39	.199	1.97	.169	Germantown, O. Substation farm. Canadian blue-grass.
4	8.17	2.33	.207	2.64	.347	Harpster, O. C. H. Lewis's farm. Canadian blue-grass.
5	6.45	1.47	.213	2.49	.262	Chandlersville, O Chas Mc.Intire's farm. Canadian blue-grass.
6	6.52	1.62	.207	2.32	.219	Average of above five samples.
7	6.31	1.89	.256	2.15	.250	Average of five samples of Kentucky blue-grass from same localities.

EFFECTS OF IRRIGATION ON MINERAL CONSTITUENTS

Samples of forage plants which had been grown either very wet or very dry were collected with the idea that an analysis of the ash might give us additional information as to the reasons for the difference, which everyone knows to exist, in the food value of wet-weather and dry-weather grass. Cattle fatten much more rapidly on dry-weather than on wet-weather grass. A number of factors favor this result:

(1) Dry-weather grass is more mature, and its nutrient compounds are more complex and generally of greater value.

(2) The succulent grass of a wet season is bulky. An animal is obliged to do more work, that is, to gather more grass, and to handle a greater weight and bulk of substance, than when eating dry-weather grass.

(3) Succulent grass is too laxative, and tends to carry the food along the digestive tract more rapidly than it can be digested.

(4) The proportion of non-proteid to proteid nutrients is greater in mature than in immature grass; that is, the nutritive ratio is "wider", and dry-weather grass is, on this account, a better fattening food.

That succulent grass may not be in the most desirable condition, as an animal food, is indicated by the common habit of insects to cut and wilt their food before eating it, and the fact that certain species can be starved by confining them to food plants which are abundantly watered. The habitual preference of insects for unthrifty plants is also probably due to the greater concentration of the sap.

While these above-mentioned reasons for the superiority of dry-weather grass as a fattening food seem sufficient to account for this fact, we have considered the possibility that the mineral constituents of the grass might also contribute an influence.

TABLE VI—EFFECTS OF IRRIGATION ON MINERAL CONSTITUENTS

Dry Matter Basis—Percent

No.	Ash	Nitrogen	Calcium	Potassium	Phosphorus	Source of Sample
1	8.62	2 32	1 67	1.80	.175	Alfalfa; Fallon, Nev.; not irrigated for five years; water table 8ft. below surface of field.
2	10 34	2.50	1 27	2.38	.220	Alfalfa; Fallon, Nev.; irrigated frequently.
3	16 38	.845	.342	.99	099	Blue-joint (*Elymus*); Fallon, Nev.; sample from dry soil
4	9 47	.766	.250	1.06	.133	Blue-joint (*Elymus*); Fallon, Nev.; sample from land continuously wet by seepage from irrigation ditch.
5	9.78	.895	.410	92	.092	Indian bunch-grass, (*Eriocoma cuspidata*) Fallon, Nev.; sample from dry soil; annual rain-fall less than three inches.
6	16.10	.734	.462	.67	.103	Indian bunch-grass, (*Eriocoma cuspidata*). Fallon, Nev.; sample from land constantly wet by seepage from irrigation ditch.
7	12.11	1.89	1.00	2.14	.142	Bermuda grass. Yuma, Ariz. Not irrigated.
8	11.46	1.39	.709	1.55	.243	Bermuda grass. Yuma, Ariz. Irrigated frequently.

In examining the analyses in Table VI, page 50, we note that of the various constituents determined, only one varies consistently with the amount of water available to the plants. The phosphorus in each case is higher in the plants grown with abundance of water than in those grown dry. This may have been only a coincidence. More extended study will be required to settle this point.

The influence of wind-blown dust, of irrigation sediment, and of leaching, on the mineral constituents, is quite possibly so great as to render figures like the above without value in this connection.

The only way in which such a low phosphorus content of dry-grown forage as we have here noted could contribute to the superior fattening qualities of dry-weather grass, would be that, if the amount of phosphorus in dry-weather grass were insufficient to sustain maximum growth of proteid and bony tissues, that portion of the food protein which was unaccompanied by the mineral elements essential to growth would be used for fattening.

Data are not available for the determination of this point, and these figures which we publish should be considered rather to raise the question than to settle it. The reputed prevalence of osteomalacia, or malnutrition of the bones, after periods of excessive drought, and in regions of deficient rain-fall, and the amenability of this trouble to treatment with calcium phosphate, suggest that there may be a problem here which is worthy of the attention of the student.

In an effort to get experimental evidence on the effects of varying amounts of moisture on the composition of grass, we raised oat plants in pots in a greenhouse, and then analyzed the growth above ground. The results of this work are set forth in Table VII, page 52.

The amounts of moisture supplied are of significance only in a comparative way, since we made no effort to prevent evaporation of water from the soil, though conditions as to heat and light were kept constant.

Eight plants were grown from seed in each pot. We were forced to terminate each experiment earlier than was planned on account of the appearance of blade blight.

The figures in the first experiment represent averages from two pots; in the second and third the figures represent single pots; and in the fourth experiment the figures are averages from three pots.

The following conclusions may be drawn from these analyses:

(1) The percentages of moisture, ash, and phosphorus in the oat plant vary in an orderly way according to the amount of moisture available during growth.

(2) The nature of the effect of increased soil moisture depends, in a measure, on the stage of growth of the plant.

(3) In the early stages of growth of oats increased moisture increases to a slight extent the percentages of moisture and phosphorus in the plant.

The variations in the ash content of these oat plants descend regularly in the first series and ascend regularly in the second. In the third and fourth series the ash content first rises and then falls.

We probably have in each case a different part of the same simple curve; the length of time necessary for its complete expression depending on the various conditions of growth.

TABLE VII—ANALYSES OF OAT PLANTS GROWN WITH DIFFERENT AMOUNTS OF WATER.

Dry Matter Basis—Percent

Lot	Total water applied to each pot C. C.	Moisture in plant Percent	Ash in dry substance Percent	Phosphorus in dry substance Percent	Calcium in dry substance Percent
		Planted Oct. 7, 1908; cut Nov. 20, 1908			
1	1675	86 11	16 77	.884	.526
2	2420	88 51	15 38	898	.451
3	3165	88 20	15 12	966	461
4	3910	87 77	14 72	979	.515
5	4655	88 06	13 96	892	.453
		Planted Dec. 13, 1909; cut Feb. 26, 1910			
6	1800	83 78	15 17	.617	.440
7	3100	84 57	15 17	.666	.409
8	4400	86 79	15 65	.805	.498
9	5700	87 28	16 02	.787	463
10	7000	87.75	16 20	855	463
		Planted Dec. 13, 1909; cut Mar. 7, 1910			
11	2400	79.68	15 37	.684	.461
12	4000	82.44	16.19	.768	.504
13	5600	85.94	16.20	.801	.495
14	7200	85.18	16.18	.818	.488
15	8800	84 76	15 98	.809	.480
		Planted Apr. 4, 1910; cut May 11, 1910			
16	800	88 97	18.47	1.12	.542
17	1425	89 59	18 68	1.16	.539
18	2000	89 95	18 51	1.20	.554
19	2625	90.50	18 20	1.22	.493
20	3300	90.73	18.05	1.27	.551

CONCLUSIONS

Blue-grass from different situations varies greatly in its content of mineral elements. Some blue-grass pastures in Ohio contain twice as much mineral nutriment as others. Blue-grass samples, all at the same stage of growth, from Ohio and Kentucky, vary in ash between 4.80 and 8.66 percent, in calcium between .135 and .424 percent, in potassium between 1.41 and 2.85 percent, and in phosphorus between .164 and .403 percent.

Canadian blue-grass is generally somewhat more woody, and was found to be richer in potassium than Kentucky blue-grass, but not so rich in nitrogen, calcium and phosphorus, and on these accounts is probably not so valuable a food.

An abundance of moisture during growth increases, to a slight extent, the phosphorus content of grass and certain other forage plants.

Soils which are naturally rich produce blue-grass which is high in content of mineral elements, but manure and other fertilizers, when applied to poor soils, also produce blue-grass which is rich in mineral nutrients.

Both organic and inorganic phosphorus may be increased in blue-grass by the use of fertilizers, but inorganic phosphorus, which is useful in the growth of bone but not other tissues, may be increased to a much greater extent than organic phosphorus compounds, some of which contribute to the growth of all animal tissues.

It seems likely that the organic phosphorus in blue-grass is present in sufficient amount to sustain normal growth of animals, but the need for inorganic phosphorus is much greater, and on infertile pastures we may be able to grow better bone, at least, by feeding calcium phosphate.

Calcium phosphate may be fed *ad libitum*, mixed with salt; or it may be fed mixed with the ration. It may also be indirectly administered by using on the pastures fertilizers containing calcium and phosphorus.

For growing or milk-giving animals we would give about ½ pound of bone-flour per 100 pounds of air-dry feed. As long as the various rations with which the bone-flour would be fed would vary so widely in their contents of bone-food, it is impossible to make any recommendation as to quantity to be fed which would apply equally well in all cases, but since the preparation is harmless and is ordinarily worth its cost as a fertilizer alone, the exact amount given is not important. This bone-flour may be purchased from the Michigan Carbon Co., at Detroit, or from other manufacturers of gelatine, or the desired nutrients may be purchased at a somewhat greater cost from drug dealers as calcium phosphate.

Note:—For data on the relation of different soils and their treatment to the composition of the wheat plant the reader is referred to Bulletin 221 of this Station.