REPORT 126

MINERAL CONTENT of ARIZONA-GROWN ALFALFA

With Particular Reference to Minor Elements

Agricultural Experiment Station
University of Arizona
Tucson

February 1956

SUMMARY

The analysis for minor elements in alfalfa hay samples from a number of Arizona ranches in nine alfalfa-growing sections of the State do not show any deficiencies or excess that could place the hay in other than a very favorable feed-value classification. Furthermore, there is no evidence of a minor element deficiency as plant food for the crop.

There is some evidence that the phosphorus content of hay from some fields may be lower than is desirable for a hay of superior nutrient quality. The phosphorus determinations indicated a number of fields where available phosphorus was rated low and probably need phosphate fertilization.

While it is the general opinion that minor elements, with the exception of molybdenum, are less available in alkaline-calcareous soils, there is no evidence that this is true for alfalfa as is shown in Table 1. It might be well to say that when assessing the minor element nutrient status of herbage, it should be recognized that the relative amounts of two or more may be just as important as the absolute content of a single minor element. For example, it has been well established that copper aids in utilization of iron in plants. Copper also has the property of reducing the adverse effects of excess of molybdenum on ruminants.

Molybdenum was the only minor element that was determined in the soil samples that were taken from the same fields as the hay samples. Particular attention was given to this element because in certain sections of Arizona and California the molybdenum content of soils and hay has been rated as high. The soil analyses and the hay analyses do show a high molybdenum content as compared to most sections of the United States where alfalfa is grown, but there is no evidence that hay samples contain toxic amounts.

Mineral Content of Arizona Grown Alfalfa with Particular Reference To Minor Elements

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The results obtained with minor elements as nutrients for both crops and livestock in many countries have made farmers and ranchers increasingly aware of their importance. Among these elements are iron, manganese, zinc, copper, molybdenum, cobalt, boron, and possibly others. They are called minor elements because they are needed in only trace quantities by plants and animals as compared to phosphorus, calcium, and nitrogen which are referred to as major elements since they are needed in comparatively large quantities. In other words, the terms minor and major refer to quantities needed by plants and animals and not to their importance as nutrients.

Serious deficiencies of minor elements have been found in widely scattered sections of the United States, particularly in Florida, and some startling results have been obtained from the application of small quantities of the salts of these elements, as fertilizer to the soil, and to the feed rations of poultry and livestock.

The appearance of minor element deficiencies in crops in Arizona is widely scattered and in most cases is associated with the high calcium carbonate percentage in the soil rather than a true soil deficiency.

Some of the minor elements play a dual role in the growing of crops; namely, they are needed as nutrients for normal healthy plant growth and, for crops used as forage, they are essential for normal health and growth of livestock. It has been suggested that for herbage crops, the importance and the effect of minor elements on the health of the animal consuming them are greater than its value to the plant itself.

It is not the purpose here to discuss the function of minor elements in animal nutrition, but only to show the mineral content of alfalfa grown in Arizona and to comment on its significance. While some of the elements are essential nutrients for both plants and animals, this is not true for all. The mineral analyses of alfalfa presented in this report were made in order to help answer repeated requests for such information.

Many analyses have been made of Arizona-grown alfalfa, but in most part the determinations have been protein and crude fiber. The protein percentage varies greatly with the stage of growth and the season. The mineral elements calcium, phosphorus, and potassium are influenced more by soil fertility than by stage of growth and season.

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There has been little or no information available on the minor elements in Arizona-grown alfalfa. In most part these elements are present in greatest amount in the leaves and actively growing tissue of all plants and might, therefore, vary with the ratio between the stem and leaves. The alfalfa samples on which analyses are reported here were taken between May 15 and July 15 and represent the bloom stage of growth.

Collection of Samples

With the assistance of County Agricultural Agents in the State, the alfalfa samples, and in some cases soil samples, were collected from 9 alfalfa-growing areas. There were 5 samples from the Yuma Valley, 2 from the Yuma Mesa, 2 from the South Gila Valley, 8 from Pinal County, 16 from Maricopa County, 1 from Graham County, 10 from Cochise County, and 4 from Coconino County.

These hay samples were analyzed for phosphorus, potassium, and nitrogen as major elements and for iron, manganese, zinc, copper, molybdenum, cobalt, and boron as minor elements. The term "minor element" is used arbitrarily here. Other words used in reference to the minor elements are trace elements, micro elements, and micro nutrient elements. The analyses of the hay samples are given in Table 1 and the soil analyses in Table 2.

Discussion of Analyses

Iron. Iron is an essential nutrient element for both plants and animals, and the knowledge of this has existed for many years.

While some crops in Arizona have shown iron deficiency symptoms, there has been no evidence of this in alfalfa. Many analyses of leaves from plants growing in Arizona have been made in this laboratory, and most of these have shown an abundance of iron. The iron deficiency symptoms are usually caused by an immobilization of iron in the plant rather than to a restricted uptake or a deficiency in the soil. Most Arizona soils contain 3 to 5 per cent iron.

The iron content of the samples given in Table 1 varied between 50 and 1,500 parts per million (p.p.m.), and there is only one sample that might be considered low; namely 50 p.p.m. Data published by Beeson (4) representing alfalfa hay from widely separated sections of the United States showed a variation of 132 to 1000 p.p.m. iron. The data in Table 1 indicate that Arizona-grown alfalfa is well supplied with iron.

Manganese. The element manganese is present in some form in all plants and animals and is essential for normal health in both. Manganese is somewhat related to iron in its properties. Manganese deficiency symptoms have not been observed on alfalfa. (Manganese deficiency symptoms have been observed on citrus trees in Arizona, but not on any other crops.)

The analyses of the alfalfa hay samples given in Table 1 vary between 63 and 225 p.p.m. manganese. If we compare these analyses with the analyses of alfalfa hay samples from other parts of the United States (4), which vary between 14 and 936 p.p.m., the Arizona alfalfa may be classed as average to good manganese content.

Zinc. This element plays an important part in the nutrition of both plants and animals.

Analyses of leaf samples from a number of Arizona crops have not shown any evidence of a deficiency. The analyses given in Table 1 show that the zinc values varied between 10 and 77 p.p.m. For comparison Beeson has recorded (4) analyses of alfalfa hay varying between 14 and 112 p.p.m. zinc. The analyses given in Table 1 indicate that Arizona-grown alfalfa is amply supplied with zinc.

Copper. The minor element content of most crops from high to low is in the following order: iron, manganese, zinc, and copper; but copper is nonetheless essential as a mineral nutrient for livestock. The analyses of the alfalfa hay samples given in Table 1 vary between a minimum of 11 and a maximum of 27 p.p.m. These values are high compared to analyses of alfalfa from other sections of the United States and recorded by Beeson (4); namely, 4 to 15 p.p.m. There is evidence that copper functions in increasing the ability of plants to utilize iron and to reduce the toxic effects of excess molybdenum on livestock In Scotland where there is a copper deficiency in herbage (8), less than 4 p.p.m. copper in herbage is considered deficient for animal feeding.

Boron. This element is very definitely essential for the growth of crops, but there is no evidence that it has any value as a nutrient for livestock.

There is a plentiful supply of boron in Arizona soils and irrigation waters. Therefore, in this State we are concerned with an excess rather than a deficiency. The analyses given in Table 1 show a variation of 25 to 100 p.p.m. boron. If we compare this with a range of 4 to 32 recorded by Beeson (4), it is evident that Arizona-grown alfalfa is plentifully supplied with this element. Further information on boron in Arizona-grown alfalfa is available in Technical Bulletin 118 of the Arizona Agricultural Experiment Station.

Cobalt. The quantity of cobalt present in plants is so minute that it received little attention or recognition until it was discovered to be a constituent of herbage which is highly essential as a nutrient for livestock.

In the United States a deficiency of cobalt in herbage has been found in Michigan, Florida, Wisconsin, and South Carolina. In Michigan (10) hay containing 0.03 to 0.06 p.p.m. cobalt was found to be deficient as a nutrient for livestock, and 0.12 p.p.m. was found in non-deficient herbage. Analyses of natural herbage in South Carolina (5) showed that less than 0.07 p.p.m. cobalt was presumed to be deficient. Studies in Scotland (8) where a serious cobalt deficiency exists showed that herbage containing more than 0.08 p.p.m. cobalt is necessary to insure complete livestock health. "Below this there is a transition range from about 0.05 to 0.08 p.p.m. where trouble may occur. Below 0.04

Table 1. Analyses of Alfalfa Hay From Arizona Ranches. Protein, Phosphorus, Potassion, Sodium as Percent Air Dry Materials, All Others as Parts per Million Air Dry Material.

Sample Number	Phosphorus %	Potassium %	Sodium %	Protein* %	Iron p.p.m.	Manganese p.p.m.	Copper p.p.m.	Zinc p.p.m.	Molbdenum p.p.m.	Boron p.p.m.	Cobalt p.p.m.
					Yuma Valley						
1	0.20	2.05	.12	19.5	240	137	13	57	4.6	50	.085
4	.29	2.75	.12	19.2	380	94	12	10	6.8	45	.090
5	.28	2.10	.22	22.7	280	220	12	27	5.7	25	.105
7	.23	2.15	.12	19.6	405	158	12	35	6.7	45	.115
9	.33	1.95	.15	21.8	341	156	15	37	7.6	80	.090
					Yuma Mesa						
2	.26	1.90	.15	22.6	115	169	12	40	5.0	100	.105
8	.27	2.15	.05	16.7	115	169	12	35	6.7	75	.095
					South Gila Valley						
3	.26	1.85	.17	22.3	105	65	12	35	5.7	100	.105
6	.33	1.90	.30	16.2	122	137	12	37	6.1	50	.080
					Pinal County						
10	.30	2.45	.40	27.7	220	90	12	50	4.6	80	.105
11	.29	2.70	.35	26.4	315	194	12	50	6.6	82	.100
12	.30	2.35	.10	16.3	292	225	12	32	3.0	75	.090
13	.40	2.50	.45	17.8	312	175	12	37	2.5	79	.115
14	.22	2.42	.35	21.8	363	63	12	42	3.3	75	.175
21	.31	2.30	.11	16.3	143	150	12	25	4.4	68	.145
22	.33	2.10	.10	20.0	160	188	13	30	3.3	66	.148
41	.27	1.80	.09	17.0	615	171	12	52	6.4	50	.125
					Graham County						
18	.33	2.75	.25	21.9	130	137	13	42	3.8	71	.120
					Pima County						
38	.23	2.77	.17	12.5	560	83	21	52	3.6	38	.120
39	.12	2.30	.12	12.9	600	85	21	55	4.6	48	.130
40	.22	1.48	.09	14.0	450			52	4.6	45	

15	.22	2.45	.12	26.7	103	130	--	32	2.2	73	.145
16	.31	2.75	.10	15.8	50	84	12	35	2.2	68	.113
17	.27	1.32	.45	17.5	240	112	11	32	3.6	70	.125
19	.24	2.90	.20	20.8	480	165	22	47	7.3	68	.095
20	.22	2.95	.27	20.2	440	163	20	20	7.5	30	.085
32	.23	2.25	.10	18.7	430	113	13	50	4.3	37	.075
33	.16	2.35	.16	15.5	750	120	27	50	3.8	37	.100
34	.21	1.95	.12	16.6	600	113	12	47	1.0	37	.110
35	.20	1.70	.10	19.7	630	197	21	45	1.0	40	.115
36	.23	1.70	.12	15.6	570	140	18	47	1.0	75	.100
37	.18	2.88	.12	17.6	250	147	21	55	1.2	60	.100
43	.27	1.40	.10	20.2	920	130	12	47	4.2	47	.110
44	.24	1.08	.10	18.2	980	125	12	52	4.1	52	.095
45	.31	1.33	.06	18.7	800	100	12	56	4.2	49	.110
46	.29	1.00	.10	15.3	880	110	11	35	5.2	58	.120
Cochise County											
25	.17	2.77	.25	16.3	245	113	12	50	2.4	25	.100
26	.16	2.95	.30	17.8	380	125	13	52	2.3	35	.095
27	.17	2.67	.20	15.0	200	133	12	70	3.6	30	.125
28	.24	2.75	.25	18.8	1000	137	12	42	4.9	40	.090
29	.25	3.05	.25	17.4	400	137	14	30	2.3	70	.100
30	.24	2.25	.12	18.6	700	144	20	25	4.6	40	.115
31	.23	1.90	.10	20.5	215	133	10	51	4.2	28	.125
42	.25	1.45	.07	22.9	816	75	10	51	4.2	28	.100
23	.18	2.80	.25	18.2	290	150	77	53	4.8	28	.125
24	.17	2.67	.20	24.1	288	163	17	52	3.5	60	.085
Coconino County											
47	.33	3.08	.20	16.2	900	110	11	60	5.2	43	.185
48	.32	2.83	.25	15.8	1500	130	11	72	5.5	72	.180
49	.35	2.83	.25	17.3	990	115	12	67	4.7	61	.180
50	.32	2.88	.25	18.0	600	150	12	77	5.2	49	.075
51	.37	3.00	.22	17.2	1000	135	11	65	3.9	60	.175

*Nitrogen percentage is given as percent protein. Insect damage was responsible for unusually low protein percentages in many samples.

p.p.m. cobalt, it is unlikely that healthy permanent sheep stock can be carried" (8). This detailed discussion on cobalt is given here because alfalfa too is just as important as other herbage, and the recognition of this mineral is of more recent date than most of the other minor elements.

Most of the alfalfa hay analyses given in Table 1 show more than 0.10 p.p.m. cobalt. The lowest analysis is 0.075 p.p.m. These analyses show a fair to good cobalt content for Arizona-grown alfalfa.

Molybdenum. There was a dual purpose involved in the examination of molybdenum as one of the minor elements in Arizona alfalfa; namely, the molybdenum content of the hay as a plant nutrient and as an ingredient that can adversely affect the feeding value of the hay. Excess molybdenum in hay is toxic to ruminants. The latter is of particular interest where alfalfa is grown in calcareous soils because uptake of molybdenum by plants from alkaline-calcareous soils is much more active than in non-calcareous soils.

The analyses of the alfalfa samples are given in Table 1. Judging from the literature on this subject, there is more interest in molybdenum content of herbage than in the molybdenum content of the soil because there are certain factors which have a marked influence on uptake by plants.

Robinson and Edgington (6) analyzed alfalfa hay samples from a number of states among which Arizona was included. These analyses are reproduced here:

State	*p.p.m. Mo.*	*State*	*p.p.m. Mo.*
Michigan	**0.9 to 2.3**	**Virginia**	**0.1 to 5.3**
North Carolina	**0.2 to 7.5**	**Washington**	**1.8 to 5.3**
Ohio	**0.2 to 1.5**	**Arizona**	**4.3 to 7.7**
South Carolina	**0.3 to 0.5**	**California**	**6.4 to 9.0**
Tennessee	**0.1 to 4.7**	**Alabama**	**1.6**

They rate Arizona and California as high in the classification of these analyses. Their work confirmed previous observations that liming the soil, or the presence of calcium carbonate in the soil, increases molybdenum uptake by alfalfa. Stout (9) found that phosphate fertilization increased, and sulfate salts reduced molybdenum uptake by plants. Severe toxic effects on cattle from high molydenum in herbage have been observed in the San Joaquin Valley in California (1,2,3). In the study of this problem, Barshad analyzed a large number of hay samples from this area. These analyses showed that there was a toxic effect where the herbage contained 20 or more parts per million molybdenum, whereas there were no adverse effects observed when the molybdenum content of the herbage was less than 10 p.p.m.

On the basis of the alfalfa hay analyses given in Table 1 and the analyses of alfalfa and other herbages in other parts of the United States, the Arizona-grown alfalfa is well supplied with molybdenum as a plant nutrient; and while rated as high for feeding, it does not contain enough to be toxic to ruminants.

Phosphorus. This element was determined in all the hay samples because it is of major importance as a nutrient. In general, when alfalfa hay contains less than 0.15 per cent phosphorus, it is rated deficient. That is, the hay has a low phosphorus nutrient value. Two samples of hay from Maricopa County, 5 samples from Cochise County, and 1 from Pima County could well be classed as low in phosphorus; namely, 0.16 to 0.18 per cent..

Potassium. This mineral element was determined on all the hay samples. The data do not warrant any special comment other than that all samples were adequately supplied with potassium.

Soil Analyses

In order to obtain some information on the types of soil from which the alfalfa hay samples were obtained, soil samples were analyzed for most of the alfalfa fields. The chemical analyses included pH, salinity, available nitrogen as nitrate, and available (CO_2 soluble) phosphorus and potassium. In most soils, particularly alkaline-calcareous soils, analysis for minor elements has little or no value. Molybdenum is probably an exception, and there is some data in the literature with which comparisons can be made. The soil samples were therefore analyzed for "available" and total molybdenum using methods proposed by Grigg (7,11) and Robinson and Edgington (6). The data are given in Table 2.

pH. All the soils were within the range of 7.3 to 8.7 pH, and this represents the range for most of the better soils in the State.

Salinity. This is represented as p.p.m. total soluble salts. All were in the range of 200 to 1465 p.p.m. except one sample which contained 4,100 p.p.m. All the soils were therefore within a favorable salinity range except possibly a single sample.

Phosphorus. Available phosphorus, expressed as p.p.m. PO_4, varied considerably. This may have had some influence on the variation in protein percentages. There is some evidence of a phosphorus deficiency in all the soils below 10 p.p.m. PO_4.

Molybdenum. Regarding the molybdenum requirement of plants, Stout (9) tentatively estimated that 0.5 p.p.m. in the plant represents an adequate supplying power for the soil. If the soil provides in the order of 10 p.p.m. or more in dry plant material, it is rated as a high molybdenum soil. In New Zealand where critical deficiencies of molybdenum exist in the soil (11), the quantity varied between 0.3 and 3.2 p.p.m. Robinson and Edgington (6) analyzed a number of samples of soil from several sections of the United States. For 85 per cent of the soils, the range was 1 to 4 p.p.m. The range for all the soils examined was 0.6 to 12.2 p.p.m.

The analyses of the Arizona soils given in Table 2 show a range of 0.2 to 7.0 p.p.m. total and 0.01 to 2.1 p.p.m. "available" molybdenum. These analyses are quite similar to the analyses of the soils from the San Joaquin Valley where Barshad (1,2,3) found a variation of 0.1 to 9.7 molybdenum. In Table 2 it will be

Table 2. Analyses of Soils From Which Alfalfa Samples Were Analyzed; pH, Total Soluble Salt as p.p.m., PO_4, N, K, as p.p.m., Molybdenum as Available and Total p.p.m.

Soil No.	pH	T.S.S.	PO_4 Phos-phate	N Ni-trate	K Potas-sium	Mo Molyb-denum	Mo Molyb-denum
			Yuma	**Valley**		*Available*	*Total*
1	8.0	575	22	22	60	.05	1.0
4	8.3	210	21	18	45	.01	.4
5	8.2	310	23	20	17	.03	.4
7	8.7	290	27	tr	70	.04	.6
9	8.2	255	21	12	45	.02	.2
			Yuma	**Mesa**			
2	8.4	270	17	tr	30	.02	.3
8	8.2	205	17	17	20	.03	.9
			South Gila	**Valley**			
3	8.3	175	19	55	15	.04	1.0
			Pinal	**County**			
10	8.2	1465	32	15	75	.06	.3
11	8.2	975	15	4	13	.08	.2
12	8.0	730	17	tr	30	.05	.6
13	8.4	875	15	11	47	.04	1.0
14	8.4	300	20	5	20	.07	3.0
41	7.7	275	15	18	100	1.00	4.7
			Graham	**County**			
18	8.0	169	7	22	150	.09	4.7
			Pima	**County**			
38	7.8	220	12	9	55	.08	1.8
39	7.9	245	9	11	55	.20	4.4
40	7.8	215	8	12	90	.20	3.8
			Maricopa	**County**			
19	7.3	510	15	22	76	2.10	7.0
20	7.3	270	18	18	60	1.70	6.8
43	7.8	450	10	7	40	.80	3.1
44	7.9	325	4	4	60	.80	4.1
45	7.9	360	2	3	35	.90	3.9
46	7.8	255	12	tr	25	.80	4.3
			Cochise	**County**			
25	7.4	265	tr	8	47	.09	.9
26	7.6	245	21	6	55	.08	.9
27	7.6	560	3	15	57	.20	3.5
28	7.7	590	7	12	50	.31	3.6
29	7.7	515	18	tr	57	.09	2.0
30	7.5	420	12	15	65	.20	3.5
31	7.6	310	5	8	32	.09	2.9
42	7.7	280	tr	tr	35	.80	2.6
23	7.4	460	12	14	42	.80	3.7
24	7.5	360	15	8	47	.50	2.2
			Coconino	**County**			
47	7.8	520	10	28	12	.08	4.2
48	7.6	4100	18	48	155	.04	5.1
49	7.8	935	18	48	160	.09	2.8
50	7.8	705	tr	35	125	.10	3.6
51	8.0	200	10	30	135	.11	3.3

noted that the soils from the Yuma district are lowest, and those from the Salt River Valley are highest in molybdenum content.

In Tables 1 and 2, soil sample numbers correspond with plant sample numbers.

REFERENCES

1. Barshad, I. 1948 Molybdenum content of pasture plants in relation to toxicity to cattle, Soil Sci. 66:187.
2. Barshad, I. 1950 Factors affecting the molybdenum content of pasture plants: I, Nature of soil molybdenum, growth of plants, and soil pH, Soil Sci. 71:297.
3. Barshad, I. 1950 Factors affecting the molybdenum content of pasture plants: II, Effect of soluble phospates, available nitrogen, and soluble salts, Soil Sci. 71:387.
4. Beeson, K. C. 1941 The mineral composition of crops with particular reference to the soils in which they are grown, U. S. D. A. Misc. Pub. 369.
5. Beeson, K. C. 1955 Nutrient element content of native forages in relation to location and land forms in South Carolina coastal plain, Soil Sci. 80:211.
6. Edgington, G. and Robinson, W. O. 1949 The molybdenum content of alfalfa and some other crops, U. S. D. A. Res. Rep. No. 171.
7. Kidson, E. B. 1954 Molybdenum content of Nelson soils, New Zealand Jour. Sci. & Tech. Sec. A, V. 36, No. 1.
8. Mitchel, R. L. 1948 Trace constituents in soils and plants, Research 1:159.
9. Stout, P. R., Meagher, W. R., Pearson, G. A., Johnson, C. M. 1951 Molybdenum nutrition of crop plants, Plant & Soils 3:51.
10. Young, R. S. 1948 Cobalt, A. C. S. Monograph No. 108, Reinhold Pub. Co.
11. New Zealand Soil News; Molybdenum symposium, Dec., 1953; Reprinted by Climax Molybdenum Co., New York.