RESEARCH BULLETIN 724 FEBRUARY, 1960

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

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Mineral Composition of Missouri Feeds and Forages

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(Publication authorized February 8, 1960)

COLUMBIA, MISSOURI

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This bulletin reports on Department of Agricultural
Chemistry research project 147,
Forage Minerals.

Mineral Composition of Missouri Feeds and Forages

II. Alfalfa

E. E. Pickett

One of the principal activities of the spectrographic laboratory of the University of Missouri Agricultural Experiment Station has been the survey of trace element supplies in Missouri feeds and forages. The first report of this work was concerned with lespedeza, the chief hay crop of the state (1). The next largest hay crop, and gaining in importance, is alfalfa. Corn stover has also been sampled and will be reported next.

The number of samples collected and fully analyzed was not large. One hundred eighty-seven samples were collected from 59 locations in 12 counties: 15 soil types were represented but less than four samples were taken from six of them. The samples were air-dried, ground, and analyzed for ash, moisture, nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese, boron, copper, cobalt, molybdenum, and zinc.

In the earlier lespedeza survey it was thought the extracted trace element content of the associated soils should be of interest, perhaps as an indication of the trace element content which might be expected in the plants, or at any rate as a consistently determined body of data of a sort which was scanty at the time. Much time was spent in collecting and analyzing the soils. The expected correlations among soil and plant potassium and calcium were found, as well as a loose relationship between their boron contents, and a rough correlation among low values. But trace element contents were not reflected to a useful degree in the extracts prepared from the associated soils. The soils collected with the alfalfa samples accordingly have not been analyzed. For the present, whenever animal nutrition is the chief consideration, determination of the trace element content of the plants is more worth while than seeking the total or extractable trace element content of the soils. Moreover, the analytical problems are more tractable in dealing with the plants.

Samples were collected mainly from regions which are more important for alfalfa production. No attempt was made to follow the practice used in the study of lespedeza of choosing sites which had not been fertilized. Alfalfa can scarcely be grown in many places in Missouri without fertilizer. The sites chosen were simply fields encountered on private farms, with several soil types being selected in each region sampled. Fertilizer treatments were recorded as accurately as possible. The data are not intended to indicate the alfalfa-producing potential of Missouri soils, with or without fertilizer, but they should give some information on the animal feeding value of Missouri alfalfa. By resampling the same sites, as nearly as possible, for several years, and by collecting early and late cuttings, it is hoped that correction can be made for seasonal fluctuations and that the averages obtained will give a fairly accurate picture of the feeding value to be expected in the alfalfa of each region or soil type.

The widespread occurrence found of alfalfa lacking sufficient cobalt to provide good nutrition of ruminants is cause for some concern. Other work should be done to find if this low level of cobalt is generally made up by cobalt in other feeds. It is possible that cobalt supplementation should be recommended for these regions.

Some information on the molybdenum content of Missouri soils is included in this report (Table 3), extending the earlier study of the trace element content of the ten "representative" Missouri soils (7).

PROCEDURES

Sampling. The same methods were used as in collecting lespedeza (1). Early (E) cuttings were made in early June and are second or, in the southeast lowlands, sometimes third cuttings, and the later cuttings (L) are fourth cuttings, collected in late August or early September. All were collected very near to the time of normal cutting for making hay. After air drying, samples were ground in a Wiley mill fitted with an iron screen.

Analysis. Nitrogen was determined by the A.O.A.C. Kjeldahl method (2) in the Experiment Station chemical laboratory under the supervision of Dr. C. W. Gehrke. All other analyses were done in the spectrographic laboratory (Table 1). Phosphorus was determined colorimetrically by the A.O.A.C. method in a solution of dry ash of the sample. Aliquots of the same dry ash solutions were analyzed colorimetrically for iron by the o-phenanthroline method and for manganese by the periodate method (2). Boron was determined in a separate dry ashing of 2-gram samples by the curcumin colorimetric method of Truog (3).

Potassium was determined with the flame photometer in solutions obtained by extracting the dried ground plant matter with 500 parts water, shaking for 15 minutes and filtering. This procedure was tested colaboratively by several laboratories under auspices of the A.O.A.C. and found to give good precision and accuracy as compared with the A.O.A.C. gravimetric method (4).

Calcium and magnesium were determined simultaneously by spark-in-flame excitation of dry ash solutions using the Hilger medium quartz spectrograph with direct-reading attachment. Dry ash was put in solution and diluted to the final equivalent concentration of ½ gram dry matter in 100 ml. solution, after addition of relatively large amounts of KH_2PO_4, KCl, and $SrCl_2$ to achieve good spectroscopic buffering and internal standardization. The lines Mg 2795.5 Å, Ca 3933.7 Å; and Sr 4077.7 Å, all II lines, were photometered with the photoelectric channels. Precisions were ab. 1.5 percent for Ca and 2 percent for Mg, as coefficients of variation, and accuracies were similar, as determined by wet chemical analyses of several samples. Details will be sent on request.

Copper, cobalt, molybdenum, and zinc were determined at the same time by a modification of the carrier precipitation-spectrographic method of R. L. Mitchell (15). Ten-gram samples were wet ashed with nitric and nitric-perchloric-sulfuric acids. All results for these four elements in the tables are averages of at least two and often three or four runs. Precisions are about the same as those given in reference 5. The very low values for cobalt in many samples necessitated replicate runs and indeed stimulated the investigation of the efficiency of this carrier precipitation separation by the author and B. E. Hankins (5). The results of that study fully justified the use of the method for this survey. A series of three or four standards containing known amounts of these four trace elements were carried through the entire procedure, along with each group of samples, so the working curves might be corrected frequently for uncontrolled variations in exposure and photometry conditions.

The percentage of water was determined by drying small amounts of the ground air-dried samples to constant weight at 110° C. The amounts of all constituents (Table 1) are based on the air-dried rather than the moisture-free material. The average moisture content was 8.08%.

The extractable molybdenum content of the 10 representative Missouri soils is given in Table 3. The soils have not previously been analyzed for molybdenum (7). Fifty grams of soil is extracted by shaking a sample overnight with 400 ml. of ammonium oxalate-oxalic acid solution adjusted to pH 3.3. After filtering off the soil, evaporating and ashing, the extracted material is put in solution with HCl. The molybdenum is extracted with chloroform and alpha-benzoin-oxime at pH 1.5. On ashing, the extracted molybdenum is determined by the modified spectrographic procedure of Mitchell. This method is more sensitive, freer of interference, and in our hands is more reliable than the thiocyanate colorimetric method for molybdenum.

TABLE 1--MINERAL COMPOSITION OF ALFALFA (ALL VALUES BASED ON

County	Location	Soil Type	Variety	Year	Sample Number		Ash %	
					E	L	E	L
Holt	S½NW¼, S8, T60N, R37W	Marshall	Graham	1956	7-28		8.74	
Holt	NW¼SE¼, S30, T60N, R37W	Marshall	Neb. No. 12	1957	7-31	9-21	8.48	9.80
Holt	NW¼SE¼, S30, T60N, R37W	Marshall	Neb. No. 12	1956	7-27	9-29	8.38	9.84
Holt	NW¼SE¼, S30, T60N, R37W	Marshall	Neb. No. 12	1954	7-60		9.95	
Holt	SE¼NW¼, S30, T6 N, R37W	Marshall	Neb. No. 12	1954	7-61		10.34	
Saline	SE¼NE¼, S20, T51N, R22W	Marshall	Non-Hardy	1957	7-8	9-25	10.51	10.62
Saline	SE¼NE¼, S20, T51N, R22W	Marshall	Non-Hardy	1956	7-15	9-14	8.26	9.59
Holt	NE¼SW¼, S25, T61N, R38W	Marshall	Buffalo	1957	7-30	9-28	10.70	9.19
Holt	NE¼SW¼, S25, T61N, R38W	Marshall	Buffalo	1956	7-29	9-31	7.06	12.4
Saline	3 Mi. N. Marshall	Marshall		1957	7-7	9-26	8.29	10.10
Saline	SW¼SW¼, S4, T50N, R21W	Marshall	Buffalo	1956	7-14	9-19	11.5	9.44
LaFayette	NW¼NW¼, S5, T49N, R25W	Marshall	Buffalo	1957	7-4	9-20	9.56	9.62
LaFayette	NW¼NW¼, S5, T49N, R25W	Marshall	Buffalo	1956	7-11	9-30	8.44	11.15
LaFayette	NW¼SW¼, S5, T49N, R25W	Marshall	Buffalo	1957	7-3	9-19	9.83	10.41
LaFayette	NW¼SW¼, S5, T49N, R25W	Marshall	Buffalo	1956	7-9	9-28	8.28	11.52
Perry		Wabash		1957	6-89	9-37	8.17	9.37
Perry	S6, T36N, R11E	Wabash	Oklahoma	1956	6-40	9-56	9.68	10.50
Perry	S13, T36N, R11E	Wabash	Oklahoma	1957	6-90	9-47	11.38	10.10
Perry	S13, T36N, R11E	Wabash	Oklahoma	1956	6-39	9-57	7.74	10.40
Saline	10 Mi. N., 5 Mi. W. Marshall	Wabash	Buffalo	1957	7-10	9-22	9.50	10.72
Saline	10 Mi. N., 5 Mi. W. Marshall	Wabash	Buffalo	1956	7-17	9-15	6.98	9.56
Holt	W½NW¼, S10, T62N, R40W	Wabash	Dak. No. 12	1957	7-29	9-55	8.20	8.34
Holt	W½NW¼, S10, T62N, R40W	Wabash	Dak. No. 12	1956	7-34	9-20	9.10	11.9
Holt	W½NW¼, S10, T62N, R40W	Wabash	Dak. No. 12	1954	7-63		9.36	
Daviess	N½SE¼, S16, T58N, R26W	Wabash		1956	7-40	9-25	6.08	10.00
Daviess	S2, T58N, R27W	Wabash	Buffalo	1957	7-38	9-41	9.74	9.71
Daviess	S2, T58N, R27W	Wabash	Buffalo	1956	7-39		9.85	
Holt	NW¼NW¼, S31, T59N, R37W	Wabash	Buffalo	1957	7-32	9-54	11.50	9.67
Holt	NW¼NW¼, S31, T59N, R37W	Wabash	Buffalo	1956	7-31	9-21	6.57	10.19
Holt	NW¼NW¼, S31, T59N, R37W	Wabash	Buffalo	1954	7-62		11.26	
Saline	SW¼SW¼, S34, T51N, R22W	Wabash	Buffalo	1957	7-9	9-23	12.25	
Saline	SW¼SW¼, S34, T51N, R22W	Wabash	Buffalo	1956	7-16	9-16	7.62	10.84
Holt	NW¼NE¼, S15, T62N, R40W	Wabash	Dak. No. 12	1957	7-28	9-56	10.60	9.67
Holt	NW¼NE¼, S15, T62N, R40W	Wabash	Dak. No. 12	1956	7-33	9-22	7.23	11.52
Holt	NE¼NW¼, S25, T59N, R38W	Wabash	Buffalo	1957	7-33	9-40	9.45	10.80
Holt	NE¼NW¼, S25, T59N, R38W	Wabash	Buffalo	1956	7-32	9-27	8.63	10.82
Daviess		Shelby		1957	7-36	9-57	6.91	8.96
Daviess		Shelby		1957	7-37	9-60	7.71	8.75
Daviess	SW¼SW¼, S32, T61N, R26W	Grundy		1956	7-37	9-24	7.93	7.94
Daviess	SW¼SW¼, S32, T61N, R26W	Grundy		1954	7-58		9.45	
Daviess	SW¼NE¼, S8, T58N, R29W	Grundy	Kans. Com.	1957	7-34	9-29	9.35	9.41
Daviess	SW¼NE¼, S8, T58N, R29W	Grundy	Kans. Com.	1956	7-38	9-32	8.52	9.98
Daviess	SW¼NE¼, S8, T58N, R29W	Grundy	Kans. Com.	1954	7-59		10.33	
LaFayette	NW¼NW¼, S10, T48N, R24W	Grundy	Buffalo	1957	7-6	9-17	9.77	10.28
LaFayette	NW¼NW¼, S10, T48N, R24W	Grundy	Buffalo	1956	7-13	9-17	7.14	12.6
Daviess	SE¼SE¼, S33, T60N, R26W	Grundy	Buffalo	1957	7-35	9-24	8.07	7.65
Daviess	SE¼SE¼, S33, T60N, R26W	Grundy	Buffalo	1956	7-35	9-23	5.32	9.33
Daviess	SE¼NW¼, S34, T60N, R26W	Grundy	Buffalo	1956	7-36	9-26	8.94	9.71
Daviess	SE¼NW¼, S34, T60N, R26W	Grundy	Buffalo	1954	7-57		10.09	
LaFayette	NW, S25, T44N, R26W	Grundy	Buffalo	1957	7-5	9-18	10.30	12.40
LaFayette	NW, S25, T44N, R26W	Grundy	Buffalo	1956	7-12	9-18	8.56	13.5
Audrain	NE¼SW¼, S33, T52N, R7W	Putnam	Buffalo	1954	7-56		8.74	
Audrain	5 Mi. E. Mexico	Putnam		1957	7-39	9-52	7.00	8.26
Audrain		Putnam		1957	7-40		7.98	

AIR-DRY MATERIAL CONTAINING MOISTURE AS I

Nitrogen %		Phosphorus %		Calcium %		Magnesium %		ybdenum p.p.m.		Zinc p.p.m.		Moisture %	
E	L	E	L	E	L	E	L	E	L	E	L	E	L		
3.57		.352		1.73		.243		39		18		8.13			
3.55	4.62	.291	.327	1.95	1.69	.296	.326	270	.086	26	23	8.59	8.70		
3.37	3.78	.273	.289	1.86		.306		132	.61	29	28	7.78	8.84		
3.93		.339		1.34		.319		2		20					
3.52		.362		1.64		.369		2		24					
3.32	4.14	.366	.335	1.84	2.48	.286	.362	248	.35	46	28	8.37	8.77		
2.69	3.60	.245	.302	1.52	2.29	.254	.359	256	.36	13	26	6.87	8.61		
4.35	5.92	.398	.492	1.74	3.46	.320	.426	336	2.2	26	29	9.55	9.41		
3.17	3.93	.223	.287	1.57	3.40	.306	.373	239	1.50	16	22	8.86	8.03		
3.13	5.06	.271	.430	1.88	1.45	.318	.321	221	.47	36	38	7.75	9.02		
4.39	2.40	.557	.207	1.85		.342		363	.125	60	22	8.21	7.83		
3.14	3.90	.250	.318	2.42	1.91	.310	.327	32	.63	38	21	8.82	6.69		
2.87	3.50	.218	.261	2.24	4.58	.303	.378	227	.22	18	23	8.35	3.98		
4.01	4.40	.370	.392	1.95	1.88	.366	.360	272	.37	37	27	10.42	8.46		
2.94	3.91	.257	.400	1.79	4.33	.285	.538	228	.24	22	35	8.29	8.87		
3.46	4.47	.316	.375	1.34	1.50	.244	.339	40	1.75	21	27	8.87	8.36		
3.38	4.41	.375	.425	1.29	1.84	.228	.403	392	1.31	20	32	8.37	7.80		
3.59	4.17	.374	.372	1.39	1.28	.226	.210	24	2.0	25	20	8.63	9.07		
3.27	5.42	.333	.662	1.52	1.50	.317	.348	377	1.75	24	36	7.60	8.14		
3.61	4.27	.357	.351	1.62	1.41	.194	.262	34	3.3	36	26	7.84	8.40		
2.65	3.96	.247		1.31	3.16	.174	.347	215	1.72	15	23	8.97	9.74		
3.19	4.16	.292	.350	1.36	1.48	.164	.360	25	2.6	21	27	8.34	9.55		
2.78	4.15	.292	.395	1.57	2.28	.225	.306	226	3.31	18	27	9.59	7.75		
2.85		.254		1.07		.211		2		13					
2.78	3.61	.235	.353	1.39	4.27	.225	.626	131	1.90	24	42	8.07	6.76		
4.24	4.46	.368	.412	1.84	1.70	.250	.282	230	.66	32	28	7.88	8.38		
3.29		.342		1.87		.395		16		38		9.88			
4.56	4.83		.431	1.79	1.80	.375	.386	1	2.4	30	34	8.68	7.82		
3.37	4.20	.304	.367	1.74		.280		2	1.37		22	8.89	8.12		
4.02		.458		1.31		.294		3		98					
3.28	4.12	.312	.348	1.73	1.95	.224	.364	2	2.3	27	35	7.62	9.12		
3.04	5.56	.235	.582	1.40	1.97	.228	.337	233	2.44	21	34	6.13	9.45		
3.88	4.46	.370	.371	1.48	1.51	.228	.236	37	2.8	24	25	8.32	5.13		
2.72	4.23	.347	.410	1.64	2.44	.313	.312	216	2.01	18	33	10.18	8.14		
3.62	4.58	.330	.435	1.62	1.52	.214	.234	21	3.6	28	19	8.81	7.08		
3.06	4.28	.295	.380	1.54	2.36	.251	.269	19	2.15	20	26	9.42	9.18		
2.78	3.85	.161	.219	1.83	1.26	.320	.284	19	.60	32	32	7.41	8.14		
2.94	4.35	.212	.360	1.84	1.69	.313	.376	70	.85	28	26	8.51	8.44		
3.41	5.16		.397	1.89	2.24	.394	.518	70	1.96	30	33	9.59	10.96		
2.61		.20		1.66		.383		2		17					
5.55	4.75	.494	.388	1.32	1.51	.250	.298	46	.93	19	29	8.31	7.53		
3.65	6.23	.338	.538	1.50	2.16	.269	.418	55	.69	29	37	8.44	8.53		
3.71		.308		1.52		.319		2		39					
3.27	4.31	.323	.341	1.96	1.59	.344	.382	39	.14	45	25	8.79	8.21		
2.61	3.46	.205	.267	1.71	3.67	.293	.520	11	.17	15	37	5.17	9.04		
4.29	4.97	.319	.366	1.67	1.96	.358	.422	54	.36	39	30	9.52	8.29		
3.42	5.33	.267	.475	1.53	2.50	.391	.520	44	.26	37	33	7.99	8.04		
3.62	4.47	.326	.345	1.77	3.13	.346	.715	41	.32	34	36	12.27	8.50		
2.89		.237		1.95		.399		2		26					
3.17	4.35	.223	.335	1.94	3.69	.278	.504	16	.24	33	31	8.06	7.23		
2.90	3.43	.182	.251	2.63		.428		12	.16	35	48	7.62	8.61		
3.28		.274		1.26		.335				19					
3.22	3.56	.322	.195	1.17	1.92	.24	.442	62	.40	24	42	9.20	9.04		
		.258		1.72		.352		58		31		8.69			

County	Location	Soil Type	Variety	Year	Sa um Nu E	L	Iron p.p.m. E	L
Boone	SE¼SE¼, S16, T48N, R12W	Lindley		1957	6-10	1.44	144	130
Boone	SE¼SE¼, S16, T48N, R12W	Lindley		1956	7-97		90	
Boone	SE¼SE¼, S16, T48N, R12W	Lindley		1954	7-52		187	
Boone	NE¼NW¼, S8, T48N, R14W	Menfro	No. N. Mex.	1957	6-10	2.52	101	93
Boone	NE¼NW¼, S8, T48N, R14W	Menfro	No. N. Mex.	1956	7-98		88	
Boone	NE¼NW¼, S8, T48N, R14W	Menfro	No. N. Mex.	1954	7-55		246	
Boone	NW¼NW¼, S22, T48N, R14W	Menfro		1957	6-10	2.45	101	79
Boone	NW¼NW¼, S22, T58N, R14W	Menfro		1956	7-99		146	
Boone	NW¼NW¼, S22, T58N, R14W	Menfro		1954	7-54		222	
Boone	NW¼SW¼, S23, T48N, R14W	Menfro		1954	7-53		191	
Perry	SW¼SE¼, S33, T35N, R13E	Menfro		1957	6-87	2.11	96	79
Perry	SW¼SE¼, S33, T35N, R13E	Menfro		1956	6-37	2.00	95	106
Perry	SW¼SE¼, S34, T35N, R13E	Menfro		1957	6-88	1.24	109	99
Perry	SW¼SE¼, S34, T35N, R13E	Menfro		1956	6-38	1.82	144	196
Pettis	SW¼NW¼, S15, T47N, R22W	Summit	Hardy	1954	7-51		194	
Jasper	SE¼SW¼, S34, T30N, R30W	Gerald	Non-Hardy	1954	7-49		209	
Jasper	NE¼NE¼, S35, T30N, R30W	Gerald		1954	7-50		250	
Jasper	SW¼SW¼, S11, T29N, R31W	Gerald	Kans. Com.	1954	7-48		316	
Audrain	1 Mi. N. Mexico	Huntington		1957	7-41	2.84	212	115
Greene	NE¼SE¼, S36, T30N, R22W	Huntington	Kans. Com.	1956	7-4	3.20	217	227
Greene	3 Mi. E., 1 Mi. S. Springfield	Baxter	Kans. Com.	1957	6-91	1.50	174	139
Greene	3 Mi. E., 1 Mi. S. Springfield	Baxter	Kans. Com.	1956	7-1	1.90	209	161
Greene	NW¼SE¼, S13, T28N, R23W	Baxter	Kans. Com.	1957	6-92	2.71	101	90
Greene	NW¼SE¼, S13, T28N, R22W	Baxter	Kans. Com.	1956	7-3		122	
Greene	SW¼SW¼, S11, T28N, R22W	Baxter	Kans. Com.	1957	6-93	1.82	114	178
Greene	SW¼SW¼, S11, T28N, R22W	Baxter	Kans. Com.	1956	7-2	2.40	108	183
Greene	NE¼SW¼, S2, T34N, R11E	Hagerstown	Oklahoma	1957	6-86	2.59	91	137
Greene	NE¼SW¼, S2, T34N, R11E	Hagerstown	Oklahoma	1956	6-35	2.25	116	134
Greene	SW¼NE¼, S17, T34N, R13E	Hagerstown	Oklahoma	1957	6-85	2.27	97	121
Greene	SW¼NE¼, S17, T34N, R13E	Hagerstown	Oklahoma	1956	6-36	2.50	138	119
Mississippi	NW¼SE¼, S36, T26N, R15E	Lintonia	Buffalo	1957	6-25	1.86	131	194
Mississippi	NW¼SE¼, S36, T26N, R15E	Lintonia	Buffalo	1956	6-27	1.90	134	122
Mississippi	SW¼SW¼, S26, T26N, R15E	Lintonia	Buffalo	1957	6-26	2.01	112	134
Mississippi	SW¼SW¼, S26, T26N, R15E	Lintonia	Buffalo	1956	6-28	3.25	226	117
Mississippi	SW¼NE¼, S32, T27N, R17E	Sharkey	Ranger	1957	6-24	2.35	164	112
Mississippi	SW¼NE¼, S32, T27N, R17E	Sharkey	Ranger	1956	6-29	2.90	210	110
Pemiscot	NE¼SE¼, S27, T18N, R11E	Sharkey	Buffalo	1957	6-29	2.04	98	142
Pemiscot	NE¼SE¼, S27, T18N, R11E	Sharkey	Buffalo	1956	6-33	2.35	119	152
Pemiscot	SW¼NE¼, S23, T18N, R11E	Sharkey	Argentina	1957	6-30	2.92	104	184
Pemiscot	SW¼NE¼, S23, T18N, R11E	Sharkey	Argentina	1956	6-34	3.31	106	154
Mississippi	2 Mi. N. Wyatt	Sharkey	Argentina	1957	6-23	3.59	137	99
Mississippi	SW¼SE¼, S2, T26N, R17E	Sharkey	Buffalo	1956	6-30	3.75	90	152
Mississippi	SE¼SW¼, S18, T27N, R17E	Sarpy		1957	6-21	2.38	142	110
Mississippi	SE¼SW¼, S18, T27N, R17E	Sarpy		1956	6-25	3.54	110	97
Pemiscot	NW¼SW¼, S30, T18N, R13E	Sarpy		1957	6-28	2.08	84	185
Pemiscot	NW¼SW¼, S30, T18N, R13E	Sarpy		1956	6-32	2.50	95	101
Pemiscot	SW¼SE¼, S21, T18N, R12E	Sarpy	Buffalo	1957	6-27	3.05	96	109
Pemiscot	SW¼SE¼, S21, T18N, R12E	Sarpy	Buffalo	1956	6-31	3.25	93	
Mississippi	SW¼SE¼, S14, T27N, R16E	Sarpy	Buffalo	1957	6-22	2.80	114	310
Mississippi	SW¼SE¼, S14, T27N, R16E	Sarpy	Buffalo	1956	6-26	3.20	94	129
					Ave	2.76	154	133
						L	E	L
						ium	Iron, p.p.m.	

Manganese p.p.m.		Boron p.p.m.		Cobalt p.p.m.		Copper p.p.m.		Molybdenum p.p.m.		Zinc p.p.m.		Moisture %	
E	L	E	L	E	L	E	L	E	L	E	L	E	L
50	78	39	15	.06	.23	11.1	13.4	1.3	1.2	24	31	7.89	4.14
28		23		.083		9.0		.91		19		7.00	
56		36		.08		10.3				19			
70	60	21	13	.05	.060	17.6	13.4	.49	.27	30	25	8.68	8.02
45		23		.04		12.0		.15		20		4.82	
60		46		.026		11.4				21			
53	53	12	24	.09	.062	19	14.0	.72	.033	29	34	5.18	8.03
48		14		.14		19		.39		32		4.56	
72		30		.10		11.4				10			
66		35		.06		9.6				18			
43	65	21	11	.17	.064	12	7.2	.52	.16	23	17	7.38	8.35
45	58	20	17	.072	.083	11.8	9.9	.27	.35	21	18	6.87	7.24
58	85	18	17	.18	.13	11	10.2	.29		20		8.83	8.63
63	70	20	19	.086	.082	14.6	13.8	.20	.19	24	27	12.00	5.63
77		55		.04		10.3				19			
102		40		.08		9.0				18			
88		42		.08		9.3				18			
115		80		.063		7.77							
62	187	23	27	.12	.56	15.5	14.1	.38	.86	23	51	7.07	8.92
63	63	18	25	.11	.20	11.9	21	.23	.43	20	43	9.05	8.98
53	94	47	20	.048	.21	10.6	8.1	.39	.12	55	25	5.99	9.78
58	53	10	15	.19	.14	14.8	13.0	.26	.21	23	31	7.68	4.83
85	65	30	18	.25	.18	13.4	12.5	.17	.22	32	27	8.03	9.54
75		29		.15		10.5		.17		20		4.99	
64	100	31	22	.47	.33	12	10.6	.65	.09	24	17	8.17	8.23
60	93	38	23	.12	.21	9.2	12.8	.17	.45	14	23	8.62	9.01
50	73	17	14	.14	.082	12	11.2	.42	.13	25	29	5.43	9.01
58	73	18	14	.054	.052	13.0	12.5	.17	.16	28	24	9.91	9.16
43	73	13	13	.16	.087	13.5	7.4	.25	.037	27	17	7.77	8.64
54	60	10	22	.08	.083	14	12.5	.19	.10	24	27	9.26	7.30
83	50	24	26	.44	.14	65	12	.31	.14	21	24	6.62	9.48
28	30	21	18	.17	.094	10.0	8.7	.32	.19	21	18	7.07	4.02
85	46	31	36		.26		11.9		1.63		20	7.13	8.94
55	63	27	21	.27	.26	18.6	18.3	1.30	.86	40	40	8.48	8.09
38	50	34	27	.13	.021	22.5	10.1	.92	.79	23	20	6.65	9.46
23	18	42	25	.078	.055	15.0	10.6	1.54	.67	34	25	7.71	8.39
35	23	33	25	.16	.15	10	10.3	1.1	2.1	25	25	7.50	9.88
22	23	21	28	.078	.090	12.9	16.8	2.5	2.20	37	47	8.38	7.48
49	23	39	25	.18	.087	9.2	14.4	1.2	2.1	22	33	7.76	9.16
23	33	38	28	.057	.030	11.2	13.5	1.45	1.06	29	28	7.37	7.78
43	30	33	37	.14	.069	8.4	22.6	.74	1.52	26	53	6.91	9.20
18	30	27	32	.056	.068	10.3	16.0	.33	.43	27	40	9.97	8.62
65	35	29	38	.25	.070	13.5	13.1	.9	.60	39	31	7.26	8.15
20	20	17	24	.061	.067	9.8	12.5	1.24	1.63	24	26	4.37	11.07
33	23	29	30	.23	.063	8.5	8.40	1.0	.56	20	20	6.89	9.62
18	10	15	19	.090	.054	8.7	8.1	1.31	.80	18	18	6.87	6.88
33	35	37	29	.25	.12	9.8	18.3	.42	1.77	20	48	8.52	9.45
28	25	27	33	.067	.10	10.0	18.9	2.3	3.4	22	38	7.26	5.81
28	28	36	24	.20	.22	10.0	8.9	1.5	1.5	19	22	3.88	7.67
15	20	29	26	.068	.076	9.2	11.6	1.52	1.68	20	24	7.71	6.51
45.8	47.3	30.8	24.6	.099	.105	13.0	13.0	.91	1.22	27.6	28.0		
E	L	E	L	E	L	E	L	E	L	E	L		
Manganese		Boron, p.p.m.		Cobalt, p.p.m.		Copper, p.p.m.		Molybdenum		Zinc, p.p.m.			

DISCUSSION

Regional differences in composition of the lespedeza and soils were considered at some length (1). The data on alfalfa are not so well adapted for regional comparisons for reasons already given. However, some of the most interesting results of this survey are of this sort.

Higher calcium contents are associated with the fertile loess soils of northwest Missouri. No such conclusion may be reached for nitrogen or magnesium. Contents of the remaining major elements, phosphorus and potassium, are a little higher in the alfalfa from the alluvial soils Wabash, Huntington, Sharkey, and Sarpy, as expected (9), especially in later cuttings. The manganese is markedly lower in the same group of samples except in those from the Huntington. Next lowest in manganese is the alfalfa from the Marshall soil; this soil produced lespedeza with the lowest manganese content and that from the alluvial Lintonia was next lowest. The regional patterns of iron content also are similar in alfalfa and lespedeza.

The most important regional difference observed is that of the cobalt content of the alfalfa. The soils of northwest Missouri regularly yield alfalfa which is low in cobalt. Low-cobalt-containing alfalfa occasionally is found elsewhere, especially on Sharkey, Sarpy, Menfro, and Hagerstown.

The molybdenum content of alfalfa from the alluvial Wabash, Sharkey, and Sarpy soils is much higher on the average than that from the upland soils (Table 2), the most pronounced regional difference to be found in the data. However, the oxalate-extractable molybdenum was medium to low in the Wabash and Lintonia soils themselves (Table 3). This may be ascribed to the relatively high organic matter content of these soils. The soil-plant relationships are complex and obscure (8).

Major Elements. Many of the stands sampled were produced virtually without aid of any fertilizer, some with only a little lime or manure. This was true especially on the alluvial and lowland soils, where most stands were three to four years old and had received no soil treatment since the preceding corn. The nitrogen, phosphorus, potassium, and calcium contents of the crops grown in 1956 with and without fertilizer are compared in Table 4.

Several considerations weaken any conclusions which might be suggested by this comparison: most of the samples grown with the use of fertilizer were taken from upland soils while nearly all of those grown without fertilizer were from bottom or alluvial soils. Not nearly enough data are available to permit estimation of effects of fertilization within given soil types. Of course the fertilization may have gone to increase yields; no data were obtained on yields. Naturally, many different sorts of fertilization were used by growers of Group II. A rough average rate for the group is about 100 pounds of 10-10-10 plus one ton of lime per acre annually for 1956 and the two preceding years. The heavier rate of fertilization used in producing the nine of Group III, about twice that of

TABLE 2--AVERAGE MINERAL CONTENT OF ALFALFA FOR DIFFERENT SOIL TYPES.

Soil Type	Number Samples	Ash %	N %	P %	Ca %	Mg %	K %	Fe ppm.	Mn ppm.	B ppm.	Co ppm.	Cu ppm.	Mo ppm.	Zn ppm.
Marshall	28	9.59	3.72	0.324	2.21	0.333	2.57	214	39.5	29.3	0.077	12.9	0.058	27.8
Wabash	40	9.72	4.02	.361	1.73	.280	3.10	137	30.6	30.5	.044	12.2	1.93	27.7
Shelby	4	8.07	3.48	.235	1.40	.324	1.93	116	58	18.5	.037	13.5	.660	30.0
Grundy	23	8.93	3.98	.322	2.03	.401	2.66	181	49.8	33.6	.072	15.0	.45	32.1
Putnam	4	7.99	3.33	.262	1.79	.342	2.37	163	74	26.3	.416	9.80	.55	29.0
Lindley	4	7.83	3.00	.267	1.68	.243	2.23	138	52.7	28	.12	10.9	1.12	23.5
Menfro	17	8.18	3.76	.351	1.75	.411	2.40	138	63.2	21.2	.088	12.9	.30	23.1
Summit	1	8.06	3.11	.200	1.63	.322	1.93	194	77	55	.040	10.3		19
Gerald	3	8.69	3.20	.227	1.89	.329	1.89	258	102	54	.075	8.69		18
Huntington	4	8.70	4.30	.414	1.52	.372	2.70	197	94	30.9	.242	15.6	.475	34.2
Baxter	11	8.39	3.94	.300	1.86	.300	2.26	144	73	26.7	.210	11.6	.263	26.3
Hagerstown	8	7.57	3.42	.320	1.57	.373	2.21	120	60.4	15.2	.92	12.0	.182	25.1
Lintonia	8	8.39	4.00	.430	1.33	.320	2.78	149	55.0	25.3	.240	12.2	.67	26.6
Sharkey	16	8.70	3.72	.413	1.54	.317	2.82	134	30.6	31.1	.090	13.4	1.28	31.0
Sarpy	16	8.04	3.56	.362	1.45	.288	2.74	118	27.0	27.6	.124	11.2	2.30	25.6

TABLE 3--OXALATE-EXTRACTABLE MOLYBDENUM IN TEN REPRESENTATIVE MISSOURI SOILS

Soil Type	Molybdenum p.p.m.
Marshall	0.195
Wabash	.136
Shelby	.091
Putnam	.204
Campbell	.076
Gerald	.128
Winfield	.182
Union	.166
Lebanon	.236
Hanceville	.077

TABLE 4--MAJOR ELEMENT COMPOSITION OF ALFALFA GROWN AT DIFFERENT LEVELS OF FERTILIZATION, 1956

Fertilization Rate (see text.)	N,%	P,%	K,%	Ca,%
I. No fertilizer, 29 samples	3.57	0.343	3.04	1.80
II. Slight fertilization 30 samples	3.58	.339	2.52	1.96
III. Moderate fertilization 9 samples, selected from Group II above	3.87	.372	2.65	1.91

Group II, from which those of Group III were selected, resulted in slight increases in average nitrogen and phosphorus content. It appears, however, that in terms of nitrogen, phosphorus, potassium, and calcium, the upland farmer grows only slightly better or no better alfalfa with fertilization, on the average, than the bottomland farmer without fertilizer.

Many of the stands were considered in poor shape at the time of collection, especially at the later cuttings of 1954 and 1956, because of drouth. Average composition of samples in these years might be expected to be inferior in regard to the major nutrients. The fact that the average contents of these elements compare very favorably with that of No. 1 graded alfalfa (6) is no doubt the result of selective hand picking of the samples with careful exclusion of grasses and weeds normally present in cut hay, and to more careful preservation and drying of the samples, resulting in high leaf-to-stem ratios. There seems to be little point in such comparisons.

For all of the major mineral constituents, nitrogen, phosphorus, potassium, calcium, and magnesium, there is a marked increase in percent from early to late cutting alfalfa (Table 1, last line).

The association between nitrogen (protein) and phosphorus, for any one region, is readily apparent; correlation coefficients were not computed.

Minor Elements

Iron and Manganese. The average iron content is 144 p.p.m. and the range 84 to 440 p.p.m. The average manganese content is 46 p.p.m. and the range 15 to 125 p.p.m. The decrease in average iron content in the later cuttings, from 154 to 133 p.p.m., probably is real. It was most pronounced in the northwest part of the state. The iron-manganese ratio is somewhat higher in the samples taken from the major alfalfa producing areas than in those from the poorer ones. Manganese does not approach an excessive level (1000 p.p.m.) in any sample. There is no danger of deficiency of either element in the alfalfa.

Boron. The average boron content of the alfalfa was 27.9 p.p.m., diminishing from 30.8 to 24.6 p.p.m. in the later cuttings. Many samples (40%) contained less than the 25 p.p.m. considered barely adequate in Indiana (19) and the average is low by comparison with that found in other studies (20). Borax or borated fertilizers were rarely used by the growers. However, the characteristic indications of born deficiency in alfalfa were rarely seen by the collectors. The present data certainly cannot be used to judge the desirability of boron amendment for alfalfa production.

Cobalt. Table 5 gives the percentages of samples found on the various soil types which may be considered deficient in cobalt for cattle (below 0.04 p.p.m. Co) and for sheep (below 0.07 p.p.m.), calculated on the moisture-free basis Cobalt-deficient alfalfa occurs commonly in Missouri, chiefly in the northwest part of the state, although the alluvial soils elsewhere, and alluvial-derived river-hill Menfro, also commonly produce it. The lespedeza was richer in cobalt: only 18 percent was deficient for sheep feeding and 12 percent for cattle feeding. To what extent the low-cobalt alfalfa may influence the health of livestock in these areas is unknown. The typical symptoms have not been observed frequently there. Presumably the condition gives rise only to borderline disorders, perhaps chiefly in late winter, so that it is confused with other diseases. This is often the case with cobalt deficiency (12).

It is not apparent that the soil conditions giving rise to these deficiencies of cobalt resemble very closely those in any of the more thoroughly studied cobalt-deficient areas, such as those of the southeastern coastal plains of the United States (10) where ground-water podsols are deficient, or the rhyolite pumice of New Zealand, or granite or sandstone-derived soils in various places. Mitchell states that loess is often markedly deficient in cobalt, but alluvial deposits or shale-derived soils seldom are (12). In the study of trace element extraction of Missouri soils, the alluvial Wabash was low in total or chemically extractable cobalt whereas the loess-derived Marshall and Shelby were relatively high. All three frequently produce cobalt-deficient alfalfa in Missouri.

TABLE 5--COBALT-DEFICIENT ALFALFA
FREQUENCY OF OCCURRENCE OF COBALT-DEFICIENT ALFALFA ON DIFFERENT SOIL TYPES

(Percentages of samples containing less than indicated levels of cobalt, based on the moisture-free plant matter.)

Soil Type	Number samples analyzed for cobalt	Percent contg. less than 0.04 p.p.m	Percent contg. less than 0.07 p.p.m
Marshall	27	26	59
Wabash	38	45	76
Shelby	4	50	75
Grundy	23	30	48
Putnam	4	25	25
Lindley	4	0	25
Menfro	17	6	41
Summit	1	0	100
Gerald	3	0	33
Huntington	4	0	0
Baxter	11	0	9
Hagerstown	8	0	25
Lintonia	7	0	0
Sharkey	16	12	31
Sarpy	16	0	19
Total samples analyzed for Co	183		
Overall percent cobalt deficient		20	44

Much further work is required to determine the seriousness of this cobalt deficiency of alfalfa in actual practice. Other feeding stuffs from the cobalt-deficient areas will have to be analyzed. Perhaps cobalt supplementation of cattle and sheep rations should be practiced there.

Copper. The copper content of alfalfa is well above that of lespedeza. The average found in the alfalfa was 12.4 p.p.m. and the range was from 7.4 to 22.6 p.p.m. The copper requirement of animals is commonly taken as 5 p.p.m. in the dry matter. The copper content of alfalfa found elsewhere is considerably lower on the average (6). No doubt the copper content of Missouri alfalfa is adequate for animal feeding and indicates a good supply of copper for production of the forage itself.

Molybdenum. The average molybdenum content of the alfalfa was 0.79 p.p.m. with individual samples showing a great range, from 0.033 to 5.12 p.p.m. Four samples contained less than 0.1 p.p.m. Mo, the level at which, according to Dick, sheep may accumulate excess copper in their livers (13). On the other hand, few samples approached the 5 p.p.m. Mo level at which sheep may show a copper deficiency. There seems little likelihood that these troubles should arise in the use of Missouri alfalfa.

Molybdenum content of the plants, especially the tops, seems an unreliable indication of adequacy of the supply of molybdenum for plant growth (14). However it is usually considered that 0.1 p.p.m. reflects an adequate supply for alfalfa. A few of the alfalfa samples, fairly randomly distributed, may contain insufficient molybdenum. Few other data have been obtained on the molybdenum status of Missouri crops or soils. The molybdenum content of the plants does not correlate with that extracted chemically from the soils using the oxalate reagent (Tables 2 and 3), although it should be restated that these soil samples were not taken at the same time or places as the plant samples.

The extractable molybdenum content of the ten soils (Table 3) does not correlate with the agricultural value of the land, contrary to total zinc, available boron, and copper and available quantities of most of the major elements in the same soil samples (7).

Zinc. The average zinc content of the alfalfa was 27.6 p.p.m. and the range 13 to 98 p.p.m. Similar amounts of zinc have been found in other studies of alfalfa and are well above the 8 p.p.m. found in deficient plants in one study (17). Zinc deficiency in forage-eating animals is not to be expected (18).

SUMMARY

Samples of alfalfa were collected in the years 1954, 1956, and 1957 from 59 locations in 12 counties within the chief alfalfa-producing areas of Missouri. They were analyzed for moisture, ash, nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese, boron, cobalt, copper, molybdenum, and zinc.

Calcium content was higher in samples from the Marshall soil and phosphorus and potassium were higher in samples from the alluvial soils than in others. Manganese was lower and molybdenum much higher in these alluvial soils than in others.

Cobalt content was lower in alfalfa collected from Marshall, Wabash, Shelby, Grundy, Sharkey, Sarpy, and Menfro than in alfalfa collected from other soils. On these soils, which include the chief soils of northwest Missouri and the alluvial soils elsewhere, 26 percent of the samples were deficient in cobalt for cattle feeding (less than 0.04 p.p.m. cobalt) and 49 percent were deficient for sheep feeding (less than 0.07 p.p.m.).

Many samples were low in boron. Amounts of the other trace elements, iron, manganese, copper, molybdenum, and zinc, indicated that supplies of these were generally adequate for good plant growth and animal nutrition.

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