EFFECT OF FERTILIZERS

On the Yield and Composition of Ranger Alfalfa Hay

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Fertilizer experiments showed that addition of phosphate fertilizers to soils low in available phosphorus and high in lime generally increased alfalfa yields. In some cases one application increased yields significantly for 5 years. The cobalt content of alfalfa was increased by addition of cobaltous chloride to soil. The manganese content of alfalfa hay was generally increased by addition of manganese sulfate to the soil, but the effect was significant for only 2 years. Copper applied as copper sulfate increased the copper content of the hay for 2 years. Addition of trace elements did not increase the yield of alfalfa hay.

ALFALFA is one of the most important forage crops in the United States, especially in states where a large amount of hay is harvested and stored for the wintering of livestock. Because of alfalfa's importance, it is desirable to determine the best methods of producing maximum economic yields of hay with high nutritive value.

Alfalfa is a heavy user of phosphorus and, thus, in areas where alfalfa has been grown for a number of years without the addition of phosphorus the soil usually becomes phosphorus deficient.

Pittman and Thorne (*3*), working in Utah, and Toevs and Baker (*6*) in southern Idaho have reported the effect of different types of phosphate fertilizers on the yield of alfalfa hay. Their studies indicate that yield is considerably increased by the application of treble superphosphate. Very little work has been done on the effect of fertilizers on the trace element content of alfalfa hay in Utah.

Experiments conducted by McGeorge and Breazeale (*2*), Thorne and Peterson (*4*), and others have shown that a considerable proportion of the phosphorus applied to calcareous soils is usually tied up in unavailable forms. McGeorge and Breazeale (*2*) indicate that on highly calcareous soils the phosphorus is most readily tied up in soils having a pH of 8.0 to 8.5. Therefore it will be of value to find the lasting effect of a single application of phosphate to a heavy user such as alfalfa on highly calcareous soils.

Thorne and Wann (*5*) and others have shown that on Utah soils orchard production is often limited by trace element deficiency. They found that iron, zinc, and manganese often limit the production of fruit in Utah orchards. Because of reports such as these and the fact that alfalfa owes a considerable amount of its importance to its high mineral content, an investigation was undertaken of the effect of phosphate fertilizers on the mineral composition and yield of the hay, and the effect of trace elements applied as fertilizers on the yield and nutritive quality of alfalfa hay. Greenwood and Pittman (*1*) have reported some effects of fertilization on the trace element composition of alfalfa hay in Utah.

Experimental Methods

These studies were set up to determine the effect of different fertilizers on the yield and composition of alfalfa hay in Utah. Tests were conducted in six counties widely distributed over Utah with the following soil types: Taylorsville silty clay loam, Utah County; Billings clay loam, Duchesne County; Mendon loam, Cache County; Mesa very fine sandy loam, Uintah County; Monticello loam, San Juan County; and Emery County where the soil type name has not been established. The fertilizer treatments consisted of levels of phosphorus pentoxide ranging from 0 to 216 pounds per acre, barnyard manure, and trace elements consisting of copper, cobalt, boron, manganese, and zinc as shown in Tables II and III. The phosphorus pentoxide was applied through treble superphosphate which analyzed 42% phosphorus pentoxide and 21% calcium oxide, plus some trace elements. An area of each farm was divided into plots of 18 × 75 feet to 40 × 371 feet.

Four replications of each fertilizer treatment and unfertilized control were made at each location. The applications were made at the time certified Ranger alfalfa seed was planted during the springs of 1947 and 1948.

Soil samples were taken from each farm before the fertilizer application. Standard methods of analysis were used in determining calcium carbonate, available phosphorus, available potassium, total soluble salts, organic matter, and pH. The determinations and results from Cache and Emery Counties are shown in Table I. The soils from all counties studied had an adequate supply of available potassium, but were generally low in available phosphorus, and had an average pH of approximately 8.0.

The yield was taken for each crop during the experiment. The copper, cobalt, and manganese contents were determined on the plant samples by colorimetric methods.

Representative data from two of the

Table I. Soil Analysis of Cache and Emery County Plots in 1947 and 1948[a]

	Cache			Emery,
	Surface	*12–24 inches*	*30–36 inches*	*0–6 inches*
pH, pasty condition	8.0	8.5	8.1	7.9
Total soluble salts, %	0.045	0.064	0.076	0.11
Organic matter, %	5.2	3.0	1.3	1.9
$CaCO_3$ lime, %	25.0	54.0	42.0	25.0
Available PO_4, p.p.m.	2.0	1.0	0.5	2.0
Available K, p.p.m.	300.0	185.0	180.0	75.0

[a] Determined as CO_2 soluble PO_4

Table II. Yield of Ranger Alfalfa Hay on Fertilized and Unfertilized Plots on Irrigated Farm, Castle Dale, Emery County, Utah, 1948 through 1952

Treatments, Pounds per Acre	*Yield, Tons per Acre*					
	1948	*1949*	*1950*	*1951*	*1952*	*Total*
54 P_2O_5[a]	3.82	2.96	1.99	1.51	1.69	11.97
108 P_2O_5	4.75	3.97	2.91	1.86	2.16	15.65
216 P_2O_5	5.52	4.99	4.37	2.86	2.76	20.50
216 P_2O_5 + 96 $CuSO_4$	5.88	5.15	4.36	2.44	3.18	21.01
216 P_2O_5 + manure[b]	6.13	6.10	5.55	4.20	4.50	26.48
12 to 15 tons poultry manure	5.36	5.41	4.92	3.78	4.55	24.02
216 P_2O_5 + trace elements[c]	6.18	5.39	4.47	3.15	2.74	21.93
Control, unfertilized	2.42	1.68	1.46	1.11	1.90	8.57
L.S.D., 0.05 level, tons per acre	0.64	0.71	0.69	0.73	0.64	

[a] P_2O_5 applied as treble superphosphate: P_2O_5 42%, CaO 21%, + some trace elements.
[b] Poultry manure, 12 to 15 tons per acre.
[c] Trace elements consisting of 48 pounds borax, 24 pounds cobaltous chloride, 97 pounds manganese sulfate, 48 pounds copper sulfate per acre.

Table III. Yield of Ranger Alfalfa Hay on Fertilized and Unfertilized Plots on Nonirrigated Farm, Petersboro, Cache County, Utah, 1949 through 1952

Treatments, Pounds per Acre	*Yield, Tons per Acre*				
	1949	*1950*	*1951*	*1952*	*Total*
84 P_2O_5[a]	1.07	1.92	3.03	3.24	9.26
168 P_2O_5	1.18	2.40	3.70	4.00	11.28
168 P_2O_5 + 100 copper sulfate	1.40	2.69	3.87	3.39	11.35
100 copper sulfate	0.89	0.85	1.57	1.37	4.68
168 P_2O_5 + 8 to 10 tons cattle manure	1.28	2.73	4.22	3.83	12.06
8 to 10 tons cattle manure	0.97	1.11	1.89	1.86	5.83
168 P_2O_5 + trace elements[b]	1.83	2.43	3.35	3.39	11.00
Control, unfertilized	0.64	0.60	1.38	1.09	3.71
L.S.D., 0.05 level, tons per acre	0.22	0.69	0.95	0.67	

[a] P_2O_5 applied as treble superphosphate: P_2O_5 42%, CaO 21%, + some trace elements.
[b] Trace elements consisting of 50 pounds borax, 35 pounds cobaltous chloride, 100 pounds manganese sulfate, 35 pounds zinc sulfate per acre.

six counties are shown, one (Emery County) representing a typical irrigated farm and the other (Cache County) representing a nonirrigated farm. The results shown in Tables II and III indicate that phosphorus pentoxide, when applied in a range of 168 to 216 pounds per acre on soils such as these, is able to effect in some areas significant increases in yields of hay as late as the fourth and fifth years after application. In other areas, even with high levels of phosphorus, small increases were indicated and for only one or two years.

As noted in Table II, on the Emery County irrigated plots the low level of phosphate, 54 pounds of phosphorus pentoxide per acre, gave a significant increase for 2 years only. The medium level, 108 pounds of phosphorus pentoxide per acre, gave a significant increase for 3 years. The highest total increase in yield on these plots came with an application of 216 pounds of phosphorus pentoxide plus 12 to 15 tons of poultry manure per acre. The trace elements seemed to have little, if any, effect on the yield in any of the counties except during the first year on the Cache County plots, where a slight increase was noted.

Table III shows results from the Cache County plots similar to those from the Emery County plots. On the plots 8 to 10 tons of cattle manure had little effect in increasing the yield, although when manure was applied with the high level of phosphorus, 169 pounds of phosphorus pentoxide per acre, it gave somewhat higher yields than the phosphorus alone. The addition of copper sulfate gave no increases in yield, but the other trace elements, with the high level of phosphorus, gave a slight increase in yield over the high level of phosphorus alone. This increase was effected only during the first year after the fertilizer application.

On the irrigated plots in Emery County the highest increase in yield from the phosphorus or manure applications was noted in the first year after application; after that, the magnitude of the increase in yield constantly decreased each year for the 5-year period. On the nonirrigated farm in Cache County the highest increase was obtained on the fourth year after application and the smallest increase was noted the first year. The higher increase, coming late in the experiment on the nonirrigated plots, could have been because 1952 was the most favorable year during the experiment for alfalfa growth in that area. It is probable that before the 1952 crop growing conditions and fertilization were both limiting factors and in the final year of the trials growing conditions were not a limiting factor, thus allowing the fertilizers to show maximum effects.

Analyses of the hay indicate that when copper, cobalt, and manganese are applied to the soil, the concentration of the elements in the plant is increased the first year or two after application. The data in Tables IV and V show the results of analysis from Cache and Emery Counties for one crop in 1949 and one crop in 1952. The copper, cobalt, and manganese concentrations in alfalfa generally were significantly increased in the 1949 crop by application as fertilizers in five of the six counties studied. Only Duchesne County plots showed no response to the application of any of these three elements. The trace element content varied from location to location and also between crops.

The lowest manganese content of the hay in Duchesne county was 15 p.p.m., and in that county the addition of 100 pounds of manganese sulfate per acre did not significantly increase the concentration of manganese in the plant. In the other counties the manganese content of the hay from the nonfertilized plots usually averaged around 35 p.p.m. and the addition of the manganese sulfate tended to increase this 4 to 5 p.p.m. The fertilizer treatments, other than the manganese sulfate seemed to have no significant effect on the manganese content of the alfalfa. Analyses of the 1952 crop indicate that none of the treatments had

any effect on the manganese content 5 years after application.

The application of cobalt in the form of cobaltous chloride at the rate of 35 pounds per acre effected significant increases in the cobalt content of the alfalfa from 1 to 2 years after application in five of the six locations. The hay from the unfertilized plots in 1949 had a cobalt content of 0.05 to 0.15 p.p.m. That year, on the plots that had received 35 pounds of cobaltous chloride per acre, the cobalt content of the alfalfa was significantly increased on all the plots except those in Duchesne County. The increase in cobalt content of the hay from the fertilized plots over that from the unfertilized plots ranged from 0.02 to 0.13 p.p.m. The phosphate fertilizers also significantly increased the cobalt content of the alfalfa in most areas. Since the phosphate fertilizer analyzed less than 0.01% cobalt, the stimulating effect of the phosphate on the cobalt uptake could have been a result of the acid effect of the phosphate, making the soil cobalt more available to the plant.

In the final year of the experiment, in some instances an increased cobalt content was present in the hay crop the fifth year after the fertilizer application.

The copper content of the hay from the unfertilized plots in the six areas studied ranged from about 4 p.p.m. in Emery County to 17 p.p.m. in San Juan County. With the application of 100 pounds of copper sulfate per acre the copper content of the hay was increased 3 to 10 p.p.m. The largest increase, 10 p.p.m., was obtained on the San Juan County plots. This area also showed the highest copper content of the unfertilized hay. In the case of copper, the phosphate fertilizer had only slight influence on increasing the copper content of the plant. Significant increases in copper were generally found following the application of manure.

Analyses of the 1952 crop show no significant differences in the copper content in alfalfa as a result of the fertilizer applications made 5 years before. The chemical analyses of the hay for the entire 5-year period have not yet been completed.

Table IV. Cobalt, Copper, and Manganese Content of Ranger Alfalfa Hay Grown on Nonirrigated Farm, Cache County, Utah

Treatments, Pounds per Acre	2nd Crop, P.P.M., Dry Basis					
	Copper		Cobalt		Manganese	
	1949	1952	1949	1952	1949	1952
84 P_2O_5[a]	5.8	8.1	0.09	0.04	25.7	31.7
168 P_2O_5	6.2	10.5	0.07	0.04	19.3	24.9
168 P_2O_5	7.7	4.7	0.12	0.04	17.8	23.9
100 copper sulfate	7.1	14.6	0.09	0.04	19.0	28.2
168 P_2O_5 + 8 to 10 tons cattle manure	5.5	7.2	0.11	0.05	16.0	33.4
8 to 10 tons cattle manure	6.8	13.6	0.11	0.05	25.8	33.8
168 P_2O_5 + trace elements[b]	8.5	13.6	0.18	0.07	33.2	33.6
Control, unfertilized	6.8	11.3	0.05	0.05	30.4	30.5
L.S.D., 0.5 level, tons per acre	0.9		0.04		4.9	

[a] P_2O_5 applied as treble superphosphate: P_2O_5 42%, CaO 21%, + some trace elements.
[b] Trace elements consisting of 50 pounds borax, 35 pounds cobaltous chloride, 100 pounds manganese sulfate, 35 pounds zinc sulfate per acre.

Table V. Copper, Cobalt, and Manganese Content of Ranger Alfalfa Hay Produced on Fertilized and Unfertilized Plots on Irrigated Farm, Castle Dale, Emery County, Utah

Treatments, Pounds per Acre	2nd Crop, P.P.M., Dry Basis					
	Copper		Cobalt		Manganese	
	1949	1952	1949	1952	1949	1952
54 P_2O_5[a]	7.1	9.1	0.09	0.04	13.1	13.6
108 P_2O_5	6.5	6.4	0.08	0.04	12.9	13.2
216 P_2O_5	5.9	12.3	0.10	0.06	11.3	11.6
216 P_2O_5 + 96 $CuSO_4$	4.6	9.9	0.10	0.05	14.4	12.7
216 P_2O_5 + manure[b]	5.1	8.3	0.10	0.04	14.6	14.9
12 to 15 tons poultry manure	6.5	8.9	0.08	0.05	12.4	17.7
216 P_2O_5 + trace elements[c]	6.7	8.8	0.12	0.06	14.9	14.0
Control, unfertilized	4.2	10.6	0.13	0.04	14.5	12.5
L.S.D., 0.05 level, tons per acre	1.7		0.03			

[a] P_2O_5 applied as treble superphosphate: P_2O_5 42%, CaO 21%, + some trace elements.
[b] Poultry manure, 12 to 15 tons per acre.
[c] Trace elements consisting of 48 pounds borax, 24 pounds cobaltous chloride, 97 pounds manganese sulfate, 48 pounds copper sulfate per acre.

Summary

The results of fertilizer experiments on Ranger alfalfa hay in six Utah counties indicate the following:

Alfalfa grown in Utah on soils testing low in available phosphorus and high in lime generally gave a high yield response to the addition of phosphate fertilizers. In several areas one application of 216 pounds of phosphorus pentoxide per acre effected yield increases significant for 5 years.

The cobalt content of alfalfa was significantly increased by the addition of cobaltous chloride at the rate of 35 pounds per acre. Increases were generally noted over the total 5-year period. Phosphate also increased the uptake of cobalt by the plant.

The manganese content of alfalfa hay was generally increased by the addition of manganese sulfate to the soil. The effect of the manganese sulfate was significant for the first 2 years of the experiment only.

Copper applied to the soil as copper sulfate significantly increased the copper content of the hay for the first 2 years of the experiment.

For the most part addition of trace elements did not influence the yield of hay.

Acknowledgment

This research was supported in part by grants from the International Minerals and Chemical Corp. and Kennecott Copper Co. The treble superphosphate used was furnished by the Anaconda Copper and Mining Co.

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Received for review March 24, 1953. Accepted April 3, 1953. Presented before the Division of Agricultural and Food Chemistry at the 123rd Meeting of the AMERICAN CHEMICAL SOCIETY, *Los Angeles, Calif.*