Application of Fertilizers to Aid Conservation on Annual Forage Range

O. K. HOGLUND, H. W. MILLER, AND A. L. HAFENRICHTER

Nursery Agronomist and Nursery Manager, Soil Conservation Service, Pleasanton, California; and Chief, Regional Nursery Division, Soil Conservation Service, Portland, Oregon

THE annual forage range of the foothills of California varies widely in yield and plant composition from year to year and with intensity of use for grazing (Talbot and Biswell, 1942; Bentley and Talbot, 1948). It has a short season of use during late winter and early spring. The forage has nutritional deficiencies in late spring and summer after it is dry (Hart *et al.*, 1932; Gordon and Sampson, 1939). Runoff and erosion occur when this range is in fair or poor condition (Grover, 1945; Rogers, 1945). The amount of residue left after grazing influences runoff and erosion, yield of forage, and date of range readiness.

The application of fertilizers is one method for improving vegetal cover for soil and moisture conservation, increasing the yield and quality of forage, and facilitating grazing management.

A study of the effect of direct application of fertilizers on annual forage range was begun in 1944 at Sunol, California. It is in the 16-inch rainfall belt and had been used for grazing since the early 1920's. Previous to this use the land had produced grain under the alternate crop-fallow system for at least 20 years. The soil was rated grade 4 (35 percent), according to Weir and Storie (1936), and has been tentatively mapped as Positas gravelly clay loam. A recent conservation survey placed it in land-capability classes III and IV. Erosion has been moderately severe, 25 to 75 percent of the surface soil having been lost. At variable depths, from 6 to 24 inches, a stiff red clay subsoil 2 to 8 inches thick is encountered, although in some small areas this clay horizon is lacking. Gravel and small stones occur throughout the profile of this mature, marine terrace soil.

Annual applications of ammonium phosphate-sulfate were made for 5 successive years. A preliminary report was made by Dickey, Hoglund, and Madson (1948). It described the methods used for measuring the effect of the fertilizer on forage and residue (stubble plus litter) production.

A small area of this range in land-capability class IV was given factorial applications of nitrogen and phosphorus, separately and in combination, in each of 4 successive years. The plots were not replicated and a new area was used each year. Lime, gypsum, and barnyard manure were applied to another unreplicated series in each of 3 successive years. In each of these trials the forage above a 3-inch stubble was harvested, dried, and weighed, but no measurement of the residue was taken.

This work was conducted by the Nursery Division, Soil Conservation Service, U. S. Department of Agriculture, Pleasanton, California, in cooperation with the University of California Agricultural Experiment Station, Davis, California.

RESULTS AND DISCUSSION

Application of Ammonium Phosphate-Sulfate

The data in Table 1 show that the annual application of 200 pounds of ammonium phosphate-sulfate (16-20-0) fertilizer increased the production of forage

from an average of 1,284 pounds to 4,166 pounds per acre. The difference was 2,882 pounds of air-dry matter and was highly significant. It represents 3.60 animal-unit-months of grazing because it is generally accepted that 800 pounds represents one animal-unit-month of feed at the stage when this forage was harvested.

TABLE 1

Effect of annual applications of fertilizers on the production of feed and residue by annual grass range[1]

SEASON	TREATMENT	HAY	RESIDUE
		Pounds for acre	
1944–45	Fertilized	[2]3,850	2,195
	Unfertilized	1,260	2,241
	Difference	[3]2,590**	−46
1945–46	Fertilized	3,661	3,220
	Unfertilized	1,259	2,900
	Difference	2,402**	320
1946–47	Fertilized	5,485	3,128
	Unfertilized	2,150	2,992
	Difference	3,335**	136
1947–48	Fertilized	3,964	3,144
	Unfertilized	861	3,528
	Difference	3,103**	−384
1948–49	Fertilized	3,852	3,760
	Unfertilized	890	3,512
	Difference	2,962**	248
Average	Fertilized	4,166	3,089
	Unfertilized	1,284	3,035
	Difference	2,882**	54

[1] The fertilizer (16-20-0) was applied at the rate of 200 lbs. per acre.

[2] Each value is the average of four replications and represents lbs. of air-dry matter.

[3] Significant at the 1% level. (**)

The increase in production from the use of fertilizer was obtained in each of the 5 years of trial. There was no season x treatment interaction. This indicates the degree to which nutrients in the soil were limiting the production of forage. Fertility limited forage production more than rainfall, or at least total rainfall did not vary enough among years to offset the beneficial effects of the fertilizers.

The level of forage production varied significantly by crop year. An exceptionally high yield was obtained in 1946–47. A study of climatic data showed that +2.74 inches of rain above the 33-year average was received in November and temperatures were slightly above average in December. However, these differences were not sufficiently great to account entirely for the increased yield. This agrees with the observations of Talbot and Biswell (1942). Total forage yield on untreated plots was low in 1947–48 and in 1948–49. In these years the untreated plots were high in percentage of broadleaf filaree (*Erodium botrys*), and low in percentage of grass.

The repeated use of fertilizer reduced the fluctuation in production of forage among years and among plots within years. The limitations of the data due to the design of the trial are recognized, but the values for C, coefficient of variation, among years were 18 percent and 33 percent respectively, for fertilized and untreated plots. The values for C for fertilized and untreated plots for the duration of the trial were 26 percent and 49 percent, respectively. For these reasons the use of fertilizer supplying nitrogen and phosphorus made for more uniform production of feed from year to year and from one part of the field to another. Both of these improvements in production facilitate grazing management and are in addition to substantial increases in yield of forage.

The use of 16-20-0 fertilizer on the annual-forage range has an important influence on the date of grazing readiness. Estimates of grazing readiness were made

in each of the last 4 years of the trial. Wild oats (*Avena fatua*), and Soft chess (*Bromus mollis*), were used as indicator plants and heights were 4 to 5 inches and 2 to 4 inches, respectively. The average date of grazing readiness on the untreated plots was March 15, and the green feed period averaged approximately 6 weeks. The average date of readiness on the fertilized plots was February 1, and the length of the green feed period was slightly more than 12 weeks. The greatest difference in grazing readiness was obtained in the 1947–48 season when effective rains were obtained early in the fall. In this season, forage on the fertilized plots reached readiness 71 days sooner than that on the untreated plots.

The application of fertilizer had no influence on the amount of residue. The averages for residue on the fertilized and on the untreated plots as shown in Table 1 were 3,089 and 3,035 pounds of dry matter per acre. The difference was not significant. The residue included both stubble and litter; no separations were made. The amount of residue increased significantly from the first year to the second, but thereafter there were no significant changes. The increase from the first to the second year doubtless represents an accumulation of litter. Although all of the hay was removed from the plots each year, no attempt was made to remove the litter. The amount of litter, approximately 1.5 tons per acre, provided adequate protection against runoff and erosion even when abnormally heavy rains occurred.

Application of Nitrogen and Phosphorus

The data in Table 2 give an indication of the relative influence of nitrogen and phosphorus on production of forage as measured by the yield of hay. The data have many limitations because the plots were small for this kind of land, there were no replications within years, and the design of the trials imposed restrictions on interpretation. Even so, there were some consistent trends.

Production of forage was increased with each additional amount of nitrogen added. This occurred in each of the 4 years, except with one treatment in one year. In the 1946–47 season less forage was produced with 84 pounds than with 61 pounds of nitrogen. The difference may not have been significant. If it was, it would indicate the possibility of a season x treatment (nitrogen) interaction that may have been caused by the hot and dry climatic conditions during the last 40 days of the growing season in that year.

No significant increases in average production were obtained by adding increments of P_2O_5. A slightly higher average yield of hay was obtained from plots receiving P_2O_5 as compared with those receiving none. The difference was approximately 400 pounds, which was not significant by the "*t*" test but was indicative of some influence from the addition of P_2O_5. There was a pronounced season x treatment (phosphorus) interaction. In the 1947–48 and 1948–49 seasons, additions of increments of P_2O_5 caused progressive increases in yield of forage. The only possible reason is that the percentage of broadleaf filaree was higher in these seasons than in the other two. Filaree may be a heavier feeder on phosphorus than are the grasses. This seems to be indicated in comparative chemical analysis made on range plants (Gordon and Sampson, 1939). There was no evidence whatever that any of the fertilizer treatments had any effect on the percentage of bur clover (*Medicago hispida*), the principal legume of this range, in any of the four seasons.

From the results of this trial it was evident that this annual-forage range will, in general, respond to additions of nitrogen. In this trial the upper limit of a direct response was not exceeded with 84 pounds

of nitrogen except in the 1946–47 season. Response to P_2O_5 was indicated, but increases in yield were not sufficiently great to be regarded as significant. Further, the addition of more than 65 pounds of P_2O_5 did not influence yields except in 1946–47 when there was a slight reduction. There was no evidence of a nitrogen x phosphorus interaction that was not masked by seasonal influences. It was quite clear that the response to nitrogen was greater than the response to P_2O_5 insofar as production of forage was concerned. The average increment of increase in production of forage per pound of nitrogen added was approximately 39 pounds. The average increment per pound of P_2O_5 would be misleading because there were no significant differences and addition of more than 65 pounds gave no consistent increases in production. Assuming a slight increase due to adding 65 pounds of P_2O_5, the increment would average about 6 pounds. These results when combined with

TABLE 2

*Effect of applying different rates of nitrogen and phosphorus, alone and in combinations, on the production of feed by annual grass range**

NITROGEN LBS./A	SEASON	P_2O_5, LBS. PER ACRE				AVERAGE
		0	65	129	172	
		Yield, pounds per acre				
0	1945–46	2028	2988	2568	1758	2336
	1946–47	2660	2998	3027	3224	2977
	1947–48	728	748	811	884	792
	1948–49	986	878	1233	1329	1106
	Average	1601	1903	1910	1799	1803
32	1945–46	3778	4128	4672	4346	4231
	1946–47	4210	4865	4455	4471	4500
	1947–48	1287	1350	1524	1723	1471
	1948–49	1751	2171	2540	2482	2236
	Average	2757	3129	3298	3256	3110
61	1945–46	4974	5624	5898	7344	5960
	1946–47	6575	5955	5718	5060	5827
	1947–48	1568	2546	3019	2078	2303
	1948–49	2230	2888	3309	3493	2980
	Average	3837	4253	4486	4494	4268
84	1945–46	6488	6808	5844	6134	6319
	1946–47	5690	5256	4933	4933	5203
	1947–48	2680	3189	3270	4329	3367
	1948–49	3140	4625	3859	4410	4009
	Average	4500	4970	4477	4952	4725
Average.....		3174	3564	3543	3625	

* Nitrogen was applied in the form of ammonium sulphate and phosphorus as single superphosphate.

observations indicating no increase in legumes on the treated plots would make the use of phosphates questionable insofar as value of forage is concerned.

per acre increased with additions of fertilizer the percentage of protein, calcium, and phosphorus in the feed decreased slightly. There were no apparent signifi-

TABLE 3

*Effect of nitrogen and phosphorus on the amount of protein, calcium and phosphorus contained in the forage of annual grass range**

PLANT NUTRIENT		YIELD OF FORAGE PER ACRE	YIELDS OF NUTRIENTS PER ACRE						CA:P RATIO
Kind	Lbs. /Acre		PROTEIN		CALCIUM		PHOSPHORUS		
		Pounds	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*	
None		2028	6.60	134	.416	8.44	.214	4.34	1.94:1
N	84								
P_2O_5	65	6808	5.50	374	.360	24.51	.182	12.39	1.98:1
N	84								
P_2O_5	129	5844	5.44	318	.308	18.00	.214	12.06	1.49:1
N	84								
P_2O_5	172	6134	5.37	329	.312	19.14	.193	11.84	1.64:1

* Grass harvested at hay stage.

The addition of fertilizer to land that produces feed for livestock may cause differences in the quality of the feed apart from the differences in the amounts that are produced. Combinations of quantitative and qualitative differences are important to the grazier. Table 3 gives the results from a preliminary test to determine trends in quality of feed as influenced by additions of nitrogen and phosphorus. The chemical determinations were made by Nelson's Laboratories, Stockton, California. The hay from the 1945–46 season was used. This season was regarded as average for climatic conditions, and the major part of the forage was grass.

With due regard for the many limitations of the data, it is quite certain that nitrogen increased production of feed and of protein per acre. There was an increase in production of phosphorus per acre, but no differences were attributable to increases in the amount of phosphorus fertilizer added. As the production of forage

cant differences among the percentages of any of these constituents as a result of different levels of phosphorus applied. The calcium-phosphorus ratio was slightly narrower in the feed from treated plots, but the average 1.70:1 was still good. The increase in production of protein, calcium, and phosphorus was due largely to increases in yield of forage per acre because there was no evidence of a change in the botanical composition due to treatment except an increase in the amount of harvestable grass. This may account for the slight decrease in the percentage of protein and phosphorus in the hay from fertilized plots. The hay from unfertilized plots contained a higher percentage of filaree which Gordon and Sampson (1939) have shown to contain more protein and phosphorus than grass. These differences are based only on observations and should be verified. Also, harvesting forage as hay above a 3-inch stubble does not represent

the feed that would be taken by a grazing animal, especially with respect to quality.

Applications of Gypsum, Lime, and Manure

Table 4 presents results from applications of gypsum, lime, and manure on the production of feed. The trials were made in each of 3 years, but there were no replications within years. The only differences in production between treated and untreated plots that were significant beyond doubt were obtained by applying manure. The manured plots also contained more bur clover than any of the others. Differences in yields obtained by adding lime and gypsum are of doubtful significance, and there were no observed differences between the botanical composition of these plots and the check. Increased forage yields accompanied by increases in the percentages of legumes have been obtained in some parts of California by the addition of sulphur (Conrad, 1950).

TABLE 4

Influence of lime, gypsum, and manure on the production of feed by annual grass range

RATE PER ACRE AND TREATMENT	FEED PER ACRE			
	1946–47	1947–48	1948–49	Average
	Pounds			
None	2660	723	986	1456
Gypsum, 2 Tons	3021	597	1106	1575
Lime, 1 Ton	3163	801	1500	1821
Manure, 10 Tons	3368	1373	3701	2814
Manure, 20 Tons	4121	2315	4882	3773
Average	3267	1162	2435	

There was a slight indication that seasonal influences may have affected the results, but they were not sufficiently consistent to allow conclusions. The level of production was highest in 1946–47 which was a good year for the grasses. In this year there may have been a slight increase from the use of lime. However, the 1948–49 season was unfavorable to grass and favorable to the growth of filaree. Manure gave significant increases in production and was the only fertilizer that increased the amount of bur clover in the hay. Even so, the percentage of bur clover was less than 10 percent and may have been caused by seed brought in with the manure.

SUMMARY

Fertilizer trials on annual-forage range have been made on Positas gravelly clay loam soil at Sunol, California since 1944.

Five years' results from repeated annual applications of 200 pounds per acre of ammonium phosphate-sulfate (16-20-0) show that this fertilizer:

1. Increased forage production by an average of 2,882 pounds, which is equivalent to 3.60 animal-unit-months per acre.
2. Reduced fluctuation in production from year to year.
3. Advanced the date of grazing readiness by 6 weeks.
4. Doubled the length of the green feed period.
5. Had no effect on the production of residue.

Four years' results from the application of three rates of nitrogen and three rates of P_2O_5, applied separately and in combination to a new set of plots each year, show that:

1. The production of forage was increased with each increase in amount of nitrogen added.
2. Forage production limits were not reached by the application of 84 pounds per acre of nitrogen.
3. Forage production was not significantly increased by applications of P_2O_5 in amounts up to 172 pounds per acre.

4. Neither fertilizer had any important effect on botanical composition.
5. Nitrogen increased both the quantity of forage and the amount of protein per acre.
6. The calcium : phosphorus ratio of fertilized forage averaged 1.70:1, while the ratio on untreated plots was 1.94:1.

Three years' results from applications of gypsum, lime, and barnyard manure show:

1. Neither lime nor gypsum had any significant effect on yield or plant composition.
2. Barnyard manure significantly increased forage yields.

ACKNOWLEDGEMENT

The authors acknowledge the advice and helpful assistance of B. A. Madson, Director, Field Stations, California Agricultural Experiment Station; L. R. Wohletz, State Soil Scientist, and W. R. Frandsen, Soil Conservationist, Soil Conservation Service; and review of the manuscript by M. W. Talbot, Associate Director, California Forest and Range Experiment Station, Forest Service; and J. P. Conrad, Agronomist, California Agricultural Experiment Station.

LITERATURE CITED

BENTLEY, J. R., AND M. W. TALBOT. 1948. Annual-plant vegetation of the California foothills as related to range management. Ecology 29: 72–79.

CONRAD, J. P. 1950. Sulphur fertilization in California and some related factors. Soil Science, 70: 43–54.

DICKEY, P. B., O. K. HOGLUND, AND B. A. MADSON. 1948. Effect of fertilizer on the production and season of use on annual grass range in California. Jour. Amer. Soc. Agron., 40: 186–188.

GORDON, AARON, AND A. W. SAMPSON. 1939. Composition of common California foothill plants as a factor in range management. Calif. Agr. Expt. Sta. Bul. 627. 95 pp.

GROVER, D. I. 1945. Range condition, Corning Soil Conservation District. U. S. Dept. Agr., Soil Conservation Service, Region 7. (processed).

HART, G. H., H. R. GUILBERT, AND H. GOSS. 1932. Seasonal changes in the chemical composition of range forage and their relation to the nutrition of animals. Calif. Agr. Expt. Sta. Bul. 543. 62 pp.

ROGERS, J. B. 1945. Range condition, Contra Costa Soil Conservation District. U. S. Dept. Agr., Soil Conservation Service, Region 7. (processed).

TALBOT, M. W., AND H. H. BISWELL. 1942. The forage crop and its management. *In* The San Joaquin Experimental Range. Calif. Agr. Expt. Sta. Bul. 663, pp. 13–49.

WEIR, W. W., AND R. E. STONE. 1936. A rating of California Soils. Calif. Agr. Expt. Sta. Bul. 599.