Steer Gains on Annual-Plant Range Pastures Fertilized with Sulphur

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Fertilization is one means of increasing livestock production and decreasing the needs for supplemental feeds on many California foothill ranges. This is accomplished, in part, by lengthening the period of the year when annual plants furnish sufficient nutritious forage to promote weight gains (Bentley and Green, 1954).

Previous studies of livestock feeding at the San Joaquin Experimental Range showed that weaner and yearling steers on unimproved range, without supplements, made average daily gains varying from 1.55 to 2.55 pounds through the *green-forage season,* barely maintained their weight through the *dry-forage season,* and lost weight during the *winter season.* Feeding supplemental concentrates during the dry-forage and winter seasons produced gains satisfactory for efficient cattle production. This unimproved range provides an adequate livestock diet only during the green-forage season from February into June in most years. The forage is deficient in crude protein during the dry-forage season, from July into October. The old roughage is leached out, and the new green vegetation inadequate in amount, during the rainy cold winter season of average years from November through January (Wagnon *et al.,* 1942).

A grazing study was started in 1949 to determine whether better livestock production could be obtained with less supplemental feeding on range fertilized with sulfur. The study was conducted cooperatively by the California Forest and Range Experiment Station, U. S. Forest Service and the Department of Animal Husbandry, University of California.

This article presents the results on steer gains and supplemental feeding rates during the first 7 years. The increased herbage production and range stocking with fertilization have been reported in a previous article (Bentley *et al.* 1958) and information on steer diets and grazing habits will be reported in another article.

Procedure

The grazing test was conducted in two pairs of pastures. Size and treatments of the areas were as follows:

Experimental areas and treatments:	Surface acres	Grazable acres
Pair 1:		
F1, fertilized	46.5	43.3
C1, unfertilized	49.6	44.7
Pair 2:		
F2, fertilized	64.2	58.8
C2, unfertilized	71.5	61.0

Before treatment each area had been moderately stocked and was estimated to have grazing capacity for 10 weaner steers through an average 6-month period.

Pasture F1 was fertilized at a rate equivalent to 60 pounds of elemental sulfur per acre in January 1949, January 1953, and December 1955. Legumes were stimulated in 1950 and production of grasses and legumes was increased in subsequent years. Pasture F2 was fertilized at a 60 pound rate February 1951, 40 pounds in October 1953, and 60 pounds in January 1956, to put its fertilization on the same time schedule as pasture F1. Herbage production was increased each year from 1952 through 1956. See Bentley *et al.* (1958) for a more detailed description of fertilization and herbage response.

In July of each year, two groups of weaner steers were placed in one pair of pastures, where they remained through the ensuing dry-forage season. Sometimes during the winter season they were then moved to the other pair of pastures where they remained through the following green-forage season. The steers were removed in July after the herbage had dried, terminating that year's phase of the study. For 5 years, 1949-53, the steers were placed first in pastures F1 and C1 and moved later to pastures F2 and C2, respectively. In 1954, pastures F1 and C1 were grazed through the three forage seasons. In 1955, reversal of pasture rotation was completed by putting the steers first in pastures F2 and C2 before moving them in January to pastures F1 and C1 (Fig. 1).

Basically, each steer group consisted of 10 animals, but extras were added in the fertilized areas in most years and occasionally extras were put in the controls. During the early part of the study, sufficient steers were not always available to stock the ranges at desired rates. Thus, from 1950 through 1952 fertilized F1 was stocked below its capacity and was more lightly

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[1]*The Experiment Station is maintained at Berkeley by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of California.*

[2]*With the Agricultural Research Service for one year when this agency cooperated in the grazing trials.*

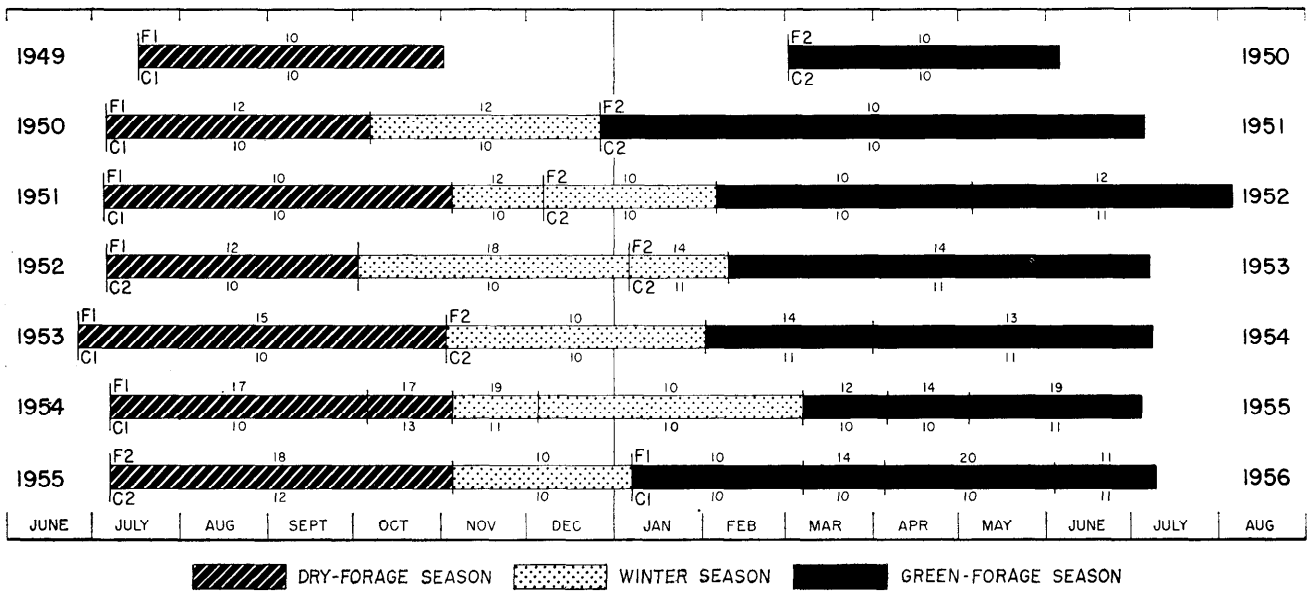

FIGURE 1. Grazing schedule for experimental pastures 1949 to 1956. Stocking by periods indicated by number of steers (small numbers along bars) in each pasture each period.

grazed than its unfertilized control. Fertilized pasture F2 was stocked more nearly to its capacity. During the last 3 years of the study, 1953-54, 1954-55, and 1955-56, when sufficient steers were available, the number of steers in each pasture was adjusted periodically (Fig. 1), and nearly full utilization of each pasture was obtained during either the dry-forage or the green-forage season. During the winter season, as each pasture was grazed to the desired degree, steer numbers were reduced to 10. Some years it was necessary to maintain larger numbers in the fertilized pastures throughout the winter season, or larger numbers were used for a short period at the start of the winter season.

The steers were choice grade weaners from the Hereford herd maintained at the San Joaquin Experimental Range and were reasonably uniform from year to year. They were weighed individually at about monthly intervals after an overnight shrink. Weaning weights were used as the initial entry weights, even though about a week was spent in the weaning lot before the grazing study was started each year.

Supplemental feeds were provided daily during the dry-forage season, except in 1950 and 1951, when the grazing of fertilized range without supplements was being tested. In subsequent years range supplements were fed at varying rates to promote weight gains of about 1.0 pound daily in each group. During the winter season each year the steers were fed daily at equal rates in both the fertilized and control pastures. Cottonseed meal pellets (41 percent protein) and rolled barley were the feeds used (Wagnon *et al.*, 1942). Alfalfa hay was fed the winter of 1953-54 because of a shortage of grazable vegetation. Supplements were not fed any year during the green-forage season. Plain salt was available at all times.

Results

The 1948-49 season was rather droughty and no response from the fertilizer applied to pasture F1 in January was noted. Pasture F2 was not fertilized until February 1951. For these reasons, the weight gains of the steer groups used in the 1949-50 season served only as further calibration of the two pairs of pastures.

Weaner steers in pastures F1 and C1 received an average of 119 and 121 pounds of cottonseed pellets, respectively, from July 20 to November 2, 1949, and gained 0.92 and 0.99 pounds daily (Table 1). They were removed from the pastures November 2, and because of cold weather and retarded plant growth were not placed in pastures F2 and C2 until March 2, 1950. These pastures were grazed, without supplements, until June 5, when failure of the water system terminated the grazing period. Average daily weight gains were 2.42 and 2.38 pounds, respectively, for pastures F2 and C2 (Table 3). These data indicate little difference between pastures.

Dry-forage Season

In 1950 and 1951, fertilization increased herbage production in F1 over that of control pasture C1, and improved the quality by increasing the legumes and reducing broadleafed filaree (Bentley *et al.*, 1958). To determine steer performance on fertilized range during the dry-forage season, no range supplements were fed during these 2 years. In 1950, the average daily gains were 0.79 and 0.09 pounds, re-

spectively, for the pastures F1 and C1 steers, while in 1951 they were 0.60 and -0.02 pounds, respectively (Table 1). Final weights were low in 1951, probably because of nutrient leaching in the herbage after a rain of 0.74 inches, which occurred 10 days before the weighing date. Earlier studies have also shown a decrease in range cattle weights after the first substantial fall rain (Wagnon). Average daily steer weight gains for the 90-day period from weaning to October 3, were 0.91 pounds on fertilized range and 0.41 pounds on unfertilized range.

Chemical analyses of herbage samples simulating that eaten by the steers in 1950 showed a variation in crude protein content from 10.46 percent at the start of the dry-forage season, to 8.25 percent at the close of the period for fertilized pasture F1, as compared to 6.99 and 4.42 percent, respectively, for unfertilized pasture C1 (Green *et al.*, 1958). Samples taken in 1951 showed similar trends but at slightly higher levels for corresponding periods for both pastures F1 and C1.

Sulfur fertilization evidently increased the crude protein content of the dry herbage sufficiently to permit moderate weight gains — ½ to ⅔ pounds daily. Comparable gains have been obtained by feeding steers a pound of cottonseed cake per head daily on unfertilized annual type range (Wagnon *et al.*, 1957). During these 2 years pasture F1 was stocked at the desired rate, and resulting herbage utilization was only moderate to light. Even so, the fertilized pasture produced 18.5 more pounds of weight gain per acre than the control pasture in 1950, and 17.4 pounds more in 1951.

Commencing in 1952, the steers in both pastures F1 and C1 were fed a range supplement during the dry season to promote equal average weight gains of about 1.0 pound per head daily. Daily gains of 0.66 pounds per head in pasture F1 and 0.73 pounds in C1 were obtained that year. On unfertilized range each steer required 34 more pounds of cottonseed meal pellets than those on fertilized pasture F1.

During the next 3 years the pastures were both stocked to fully utilize the dry herbage before the fall rains occurred. Stocking of the fertilized range was 50 to 55 percent greater than the control in the different years, but levels of utilization were about the same. Fertilized range produced 13 to 27 more pounds of steer gains per acre than unfertilized range, and in 1953 and 1954 steers on fertilized range gained at a faster rate (Table 1). Even though steers on unfertilized range received more supplements, they made smaller gains per steer day and per grazable acre.

Table 1. Herbage production, stocking, steer weights and gains and supplemental feeds, fertilized and unfertilized range, dry-forage season.

Year, grazing season and area	Herbage production per acre	Steer days per pasture	Average initial steer weight	Average daily gain per steer	Average gain per grazable acre	Average supplements per steer
	Pounds	Number[1]	Pounds	Pounds	Pounds	Pounds
1949, 7/17-11/2, 118 days.						
F1	1,354	1,050	454	0.92	25.2	119
C1	1,391	1,050	454	0.99	26.2	121
Diff. (F1-C1)	-37	0	—	-0.07	-1.0	-2
1950, 7/6-10/7, 93 days:						
F1	3,322	1,032	517	0.78	20.3	0
C1	2,842	860	516	0.09	1.8	0
Diff. (F1-C1)	480*	172	—	0.69	18.5	0
1951, 7/5-11/5, 123 days:						
F1	4,273	1,170	545	0.60	17.0	0
C1	2,495	1,170	544	0.02	-0.4	0
Diff (F1-C1)	1,778**	0	—	0.62	17.4	0
1952, 7/6-10/3, 89 days:						
F1	4,095	960	510	0.66	16.4	61
C1	2,562	800	509	0.73	14.4	95
Diff. (F1-C1)	1,533**	160	—	-0.07	2.0	-34
1953, 6/26-11/3, 130 days:						
F1	2,837	1,845	514	1.00	44.8	128
C1	1,956	1,230	514	0.86	25.5	186
Diff. (F1-C1)	881**	615	—	0.14	19.6	-58
1954, 7/7-11/5, 121 days:						
F1	3,780	1,921	525	1.18	56.0	111
C1	2,584	1,223	514	0.98	28.8	182
Diff. (F1-C1)	1,196**	698	—	0.20	27.2	-71
1955, 7/7-11/5, 121 days:						
F2	2,866	2,052	547	0.94	34.6	112
C2	1,749	1,368	548	0.90	21.5	149
Diff. (F2-C2)	1,117**	684	—	0.04	13.1	-37

1 Represents actual stocking after spending about a week of the period being weaned in a corral lot.

* Difference is significant at 5 percent level.

** Difference is significant at 1 percent level.

Table 2. Stocking, steer weights and gains, and supplemental feeds, fertilized and unfertilized range, winter season.

Year, grazing season and area	Steer days per pasture	Average initial steer weight	Average daily gain per steer	Average gain per grazable acre	Average supplements per steer
	Number	Pounds	Pounds	Pounds	Pounds
1950, 10/7-12/27, 81 days:					
F1	972	590	0.72	16.1	207
C1	810	524	0.73	13.1	207
Diff. (F1-C1)	162	—	-0.01	3.0	0
1951-52, 11/5-2/6, 93 days: [1]					
F1-F2	994	604	0.53	9.5	314
C1-C2	930	542	0.75	12.7	314
Dif. (F1,2-C1,2)	64	—	-0.22	-3.2	0
1952-53, 10/3-2/10, 130 days: [2]					
F1-F2	2,200	523	0.77	34.8	389
C1-C2	1,335	574	0.65	17.3	392
Diff. (F1,2-C1,2)	865	—	0.12	17.5	-3
1953-54, 11/3-2/2, 91 days:					
F2	910	629	-0.02	-0.4	[3]532
C2	910	626	0.09	1.4	532
Diff. (F2-C2)	0	—	-0.11	-1.8	0
1954-55, 11/5-3/7, 122 days:					
F1	1,463	671	0.26	[4]-1.1	356
C1	1,247	641	0.16	3.6	388
Diff. (F1-C1)	216	—	0.10	4.7	-32
1955-56, 11/5-1/7, 63 days:					
F2	630	659	-0.59	-6.3	183
C2	630	657	-0.56	-5.8	186
Diff. (F2-C2)	0	—	-0.03	-0.5	-3

[1] In pastures F1 and C1 first 32 days of period.
[2] In pastures F1 and C1 first 95 days of period.
[3] Includes 448 pounds alfalfa hay fed because of shortage of range herbage.
[4] Negative results due to large total weight loss of 19 steers in pasture first 27 days of period. Average daily gain is simple average of average daily gains of individual weigh periods.

Winter Season

Supplemental feeding was the same each winter season in the fertilized and control pastures except during the adverse 1954-55 season (Table 2). Average daily steer gains were about the same, indicating negligible benefits during the winter season from sulfur fertilization. The marked weight losses in both pastures during 1955-56 were due to the unusually wet weather. A total of 15.99 inches of rain was received from November 14 to December 31, 1955.

Green-forage Season

Steer gains were almost identical in pastures F2 and C2 during the green-forage season of 1950. Average daily gain was about 2.4 pounds, but the season was short (March 2 to June 5). Both pastures were utilized on the light side of moderate.

In 1951 herbage yields per acre were slightly greater in fertilized pasture F2 than in pasture C2 (Table 3). While average daily steer gains were almost identical, there were fluctuations in the growth curves of both groups. The thinner steers (not fed supplements previous dry-forage season) in unfertilized pasture C2 outgained the heavier ones in pasture F2 by 0.57 pounds daily the first 42 days. For the next 29 days they outgained the pasture F2 steers at even a faster rate, 1.10 pounds daily. Near the close of the grazing season, however, when the herbage was drying, the steers on fertilized range surpassed the others. More green herbage in the wet swales may have made the difference.

In 1952 the thinner-fleshed C2 steers outgained (by 0.37 pounds daily) the heavier-fleshed F2 steers the first 35 days of the period. However, during the next 57 day mid-season period, when the herbage was growing rapidly and approaching maturity, there was little difference in average daily gains (2.22 to 2.11 pounds respectively). Throughout this time both pastures F2 and C2 carried 10 head of steers. On May 6, stocking was increased to 12 and 11 steers respectively. In order to graze both pastures moderately, the cattle were held a month longer than usual (Fig. 1). From May 6, when range herbage was maturing rapidly, until July 3, when the range was completely dry, the pasture F2 steers outgained the others by 0.61 pounds per head daily. During the extra 34-day period the fertilized range provided a gain of 0.32 pounds per head daily, while steers on natural range lost a half pound per head daily. These results are comparable with those for the dry-forage period. Total beef production on fertilized range was 12.0 pounds per acre above that on unfertilized range.

At the start of the green forage season in 1953 and 1954, the steers in F2 and C2 were comparable in fleshing. The pastures were stocked at capacity except in mid-season 1954, when one steer in pasture F2 was lost because of urinary calculi. Early plant growth was even on both ranges, and steer gains were similar until the vegetation commenced to mature. Then the steers in the fertilized area gained more rapidly; also, their average daily gain per head for each entire season was greater (0.26 and 0.46 pounds, respectively, for 1953 and 1954). The fertilized range was stocked 27 percent heavier in 1953 and 22 percent heavier in 1954. Utilization on both areas was medium to close in 1953 and medium to light in 1954.

The greatest increase in production during the green-forage season was obtained in 1955 and 1956, when the steers were in pasture F1 and C1. This pair of pastures seemed more productive than F2 and C2 (Tables 1 and 3), and greater increases in herbage production through fertilization were obtained in pasture F1 than in pasture F2 (Bentley *et al.*, 1958). Stocking of the fertilized pasture was increased an average of 53 percent above the control in both years. Beef production in the fertilized pasture was 36 pounds per acre greater than in the control pasture in 1955 and 64.2 pounds per acre greater in 1956 (Table 3).

The two grazing seasons differed in starting date: the 1955 season started March 7, about 5 weeks later than average; the 1956, January 7, about 3 weeks earlier than average. The steers in F1 made 0.60 pounds per head greater daily gain than the C1 steers the first 30 days of 1955 and 0.93 pounds more for the first 89 days of the 1956 season. These early season gains were the result of earlier and more abundant plant growth that had been stimulated by soil nitrogen produced by a luxuriant growth of legumes the previous years (Bentley *et al.*, 1958).

Table 3. Herbage production, stocking and steer weights and gains, fertilized and unfertilized range, green-forage season.

Year, grazing season, and area	Herbage production per acre	Steer days per pasture	Average initial steer weight	Average daily gain per steer	Average gain per grazable acre
	Pounds	Number	Pounds	Pounds	Pounds
1950, 3/2-6/5, 95 days:					
F2	2,006	950	590	2.42	39.2
C2	1,788	950	596	2.38	37.1
Diff. (F2-C2)	218	0	—	0.04	2.1
1950-51, 12/27-7/6, 191 days:					
F2	3,424	1,910	652	1.66	53.8
C2	2,777	1,910	587	1.69	53.0
Diff. (F2-C2)	647*	0	—	-0.03	0.8
1952, 2/6-8/6, 182 days:					
F2	3,025	2,004	670	1.47	50.1
C2	1,844	1,912	612	1.23	38.1
Diff. (F2-C2)	1,181**	92	—	0.24	12.0
1953, 2/10-7/8, 148 days:					
F2	2,226	2,072	659	1.59	55.9
C2	1,492	1,628	652	1.33	35.5
Diff. (F2-C2)	734**	444	—	0.26	20.4
1954, 2/2-7/9, 157 days:					
F2	3,062	2,099	649	1.83	65.2
C2	2,182	1,727	641	1.37	38.8
Diff. (F2-C2)	880**	372	—	0.46	26.4
1955, 3/7-7/5, 120 days:					
F1	3,830	1,925	705	2.00	84.8
C1	2,181	1,261	652	1.75	48.8
Diff. (F1-C1)	1,649**	664	—	0.25	36.0
1956, 1/7-7/10, 185 days:					
F1	3,380	2,890	622	1.84	123.2
C1	1,970	1,886	622	1.41	59.0
Diff. (F1-C1)	1,410**	1,004	—	0.43	64.2

* Difference significant at 5 percent level.
** Difference significant at 1 percent level.

Mid-season gains for the two areas were comparable. In 1955 both groups of cattle gained about 2.2 pounds per head daily over a 59-day period. In 1956 the thinner C1 steers, which had gained less earlier, outgained the F1 steers by about 0.25 pounds per head daily for 60-day period.

Gains at the end of the green-forage season again favored the fertilized range. Steers on fertilized range outgained the control steers by 0.35 pounds per head daily during the final 31 days of 1955, and by 0.11 pounds per head daily during the final 36 days of the 1956 season.

The high production of F1 was

obtained by adding extra steers as the range vegetation developed. F1 was utilized to a moderate degree by the close of the green-forage season. In 1955, respective stocking of areas F1 and C1 and 12 and 10 steers for the first 30 days, 14 and 10 steers for the next 29 days, and 19 and 11 steers for the last 61 days. In 1956, the areas were stocked with 10 and 10 steers for the first 60 days, 14 and 10 steers the next 29 days, 20 and 10 steers for the next 60 days, and 19 and 11 steers the final 36 days. Such manipulation of livestock numbers on the range may not be entirely practical under ranch conditions, but these data indicate that a high level of stocking can be maintained through the season with some adjustment in seasons of use.

Discussion

Sulfur fertilization of foothill range lands, where effective, shows considerable promise as a means of increasing range livestock production. Prospects are especially good on the more productive land. In this study range stocking was gaged for moderate herbage utilization. Sulfur fertilization increased animal gains 20.4 to 64.2 pounds per acre during the green-forage period, and 17.4 to 18.5 pounds per acre in the dry-forage season without the use of supplements. Livestock weight gains were not increased during the winter season. Therefore the over-all increase in livestock production was confined to an 8- to 10-month period.

The average cost of fertilization, using gypsum, was about $4.50 per acre every 3 years, or $1.50 per acre per year at 1955 prices. Sulfur fertilization paid off during the green-forage season after clover growth had been stimulated. With feeder steers valued at 15 cents per pound, net returns per acre from F2 during 1953 and 1954 were $1.56 and $2.46; in the more productive F1, profits per acre in 1955 and 1956 were $3.90 and $8.13 respectively.

Although this study did not compare supplemental feeding on unimproved range with grazing on sulfur-fertilized range, some approximate comparisons are possible. In the dry-forage seasons of 1950 and 1951, without any range supplements, the steers in unfertilized C1 barely maintained their weights, while those in fertilized F1 gained 0.69 and 0.62 pounds daily. The gains in F1 are about what is expected from cattle fed 1 pound of cottonseed cake daily on unfertilized range of this type. On the average, steers on fertilized range made 64 pounds more gain in the 93-day dry-forage period of 1950 and 76 pounds in the 123-day period of 1951.

At 15 cents per pound, these gains were worth $9.60 in 1950 and $11.40 in 1951. Cottonseed cake, fed at 5 cents per pound, cost $4.65 and $6.15 per steer, leaving a margin of $4.95 and $5.25 respectively for the two years. The yearly cost of fertilization, based on total pasture acreage and the 10-steer grazing capacity of F1 before improvement, was $6.98 per steer. Thus the benefit of fertilization, that is, value of animal gain less the cost of fertilization, was $2.64 and $4.42 per steer for 1950 and 1951. But fertilization increased grazing capacity — by about 35 percent in 1950 and 65 percent in 1951. Therefore, the total return was $4.44 and $7.17 per steer for the two years. The average, $5.80, is $0.70 more than the average benefit from supplemental feeding on unfertilized range. These results could not be expected from ranges less responsive to sulfur fertilization than area F1.

Summary

Sulfur fertilization of annual type ranges provided substantial increases in range stocking and in average steer gains during the green-forage and dry-forage seasons. During the winter season it was not possible to increase stocking rates, and no advantage was shown in steer gains.

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