Fertilizers Increase Range Production

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Livestock grazing on California ranges dates from the arrival of the first Spanish colonists in 1769 (Burcham, 1957). Before that date only wild game and range rodents made limited use of these vast areas. Today, as during the past 70 years at least, these ranges are fully stocked if not overstocked with livestock. In addition, the big game population, mostly deer, is higher now than during any previous period. These factors plus drought, fire, and man's numerous devastating activities, have reduced the production of California's remaining range acres to perhaps half or less of their potential capacity (Burcham, 1957).

In the face of expanding human populations and increasing demands of other uses on the grazable acres it is imperative that every acre be wisely used for sustained high level production.

A large segment of the pristine Central Valley prairie, commonly known today as the foothill-annual range type, is the State's largest and most important range area. It encircles the Sacramento and San Joaquin valleys in a broad band between the low-lying agricultural lands and the brushfields situated just below the timber in the Sierra Nevada and Coast Range. It extends, too, into the valleys of the Coast Range and throughout the minor mountain ranges of southern California. Because of greater accessibility and milder climate, this range type has a longer and perhaps more critical grazing history than other range types in California. Aids to and management for improvement and increased production on these ranges are highly important.

Early Research

Interest in the possibilities of increasing annual type range production by fertilization was first shown by researchers and ranchers in the early 1940's. Bentley (1946), working at the San Joaquin Experimental Range near Fresno, found that pit-run gypsum gave greater increases in herbage production than either single superphosphate or sodium nitrate. About the same time the California Agricultural Extension Service and individual progressive ranchers reported good success with gypsum on range areas in several counties.

In many of these early trials the first response to fertilizers was shown by native clovers and other leguminous plants. Increased vigor and herbage growth in these species apparently added significantly to soil nitrogen through natural assimilation which stimulated grass and non-leguminous herbs to greater growth in the second years after fertilization. Bentley (1946), Bentley et al. (1958), Hoglund et al. (1952), Conrad (1950), and later Green et al. (1958) showed that the beneficial effects of the gypsum carried through three growing seasons. This finding led to a 3-year fertilization cycle and fall application. These same workers determined that plant growth started earlier, maintained a more rapid rate through the winter, and produced earlier grazing on fertilized than on unfertilized range.

Various workers in the California Agricultural Extension Service (Martin et al., undated) and the University of California (Williams et al., 1956) as well as ranchers and others, conducted numerous tests throughout the past decade with a large number of fertilizers on annual-type ranges. In general, these tests confirmed earlier findings, extended knowledge concerning several kinds of fertilizers, and gave some indications of the eco-

nomics of range fertilization. None, however, was primarily concerned with proper management of fertilized ranges or the correlation of such areas with unfertilized range in terms of a yearlong practical range-livestock operation.

The San Joaquin Study

Research on these management problems was started at the San Joaquin Experimental Range in 1958 after several years of research and experience with range fertilization (Bentley and Green, 1954; Wagnon, Bentley, and Green, 1958; and Green, Wagnon, and Bentley, 1958). New studies were designed to determine proper grazing management of fertilized ranges and how to correlate their use, yearlong, with unfertilized range. Two series of six range areas were fenced for this purpose. In each series, two units were fertilized with 60 pounds per acre of sulfur, two with 60 pounds of sulfur plus 80 pounds of nitrogen per acre, and the remaining two were unfertilized. One series was designed for green-season grazing (February to May usually), the other for use during the dry season, from May or June until the occurrence of substantial (1 inch or more) fall rain. The dry season units were fertilized in the fall of 1958 and treated again in 1961. Green season units were treated in 1959 and will be refertilized in the fall of 1962.

The cattle used in this study start out as weaned steer calves and finish about 10 months later as yearling feeder steers (Figure 1.) A new group is used each year. The basic experimental group in each unit is nine animals. Additional animals are added as needed to effect moderate utilization of the range herbage during the designated season. The grazing year starts in June or July with the dry season. When enough fall rain occurs to germinate seed and severely leach old range herbage, all animals are moved to winter range and given uniform treatment unil range readiness occurs in the green-season units. At this time each basic experimental group of nine steers is divided into three sub-groups of three. One sub-group is placed in each fertilizer treatment. This cross-over design or arrangement subjects sub-groups of animals to each fertilizer treatment and every combination of treatments. Animals are weighed individually with a light shrink at 28-day intervals and grazing use by units is recorded. Herbage production is determined annually by units as is level of utilization at the end of each grazing season.

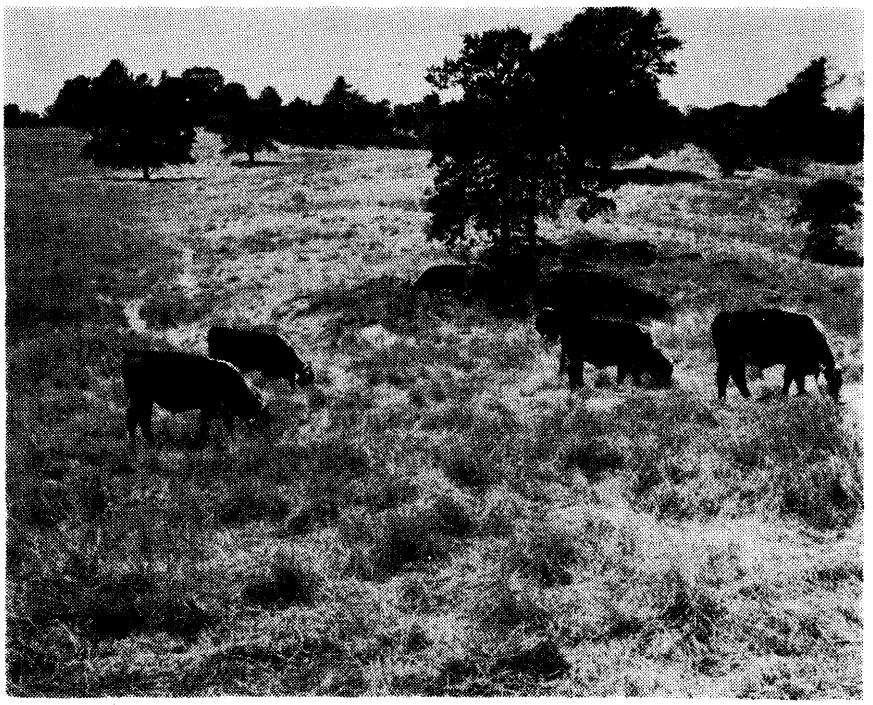

FIGURE 1. Yearling steers on fertilized annual type range late in the green season.

Results

Dry Season, 1959 and 1960

Unseasonal weather and the difficulties of starting a new procedure resulted in more variation in the first two dry seasons than was expected. At the outset, 1959 was extremely droughty and range herbage production less than half of the longtime level (Table 1). The dry-season ranges were stocked on June 1, but the short supply of herbage was soon consumed on all units and the season ended on September 9. Nine days later 3.5 inches of rain induced seed germination and plant growth, thus terminating the dry season. More than 100 days of drought following this September 18, 1959 rain proved disastrous to a high proportion of new grass seedlings on the range, thus affecting composition of the 1960 herbage (Table 2) and, of course, greatly reducing the amount of herbage avail-

Table 1. Herbage production on unfertilized and fertilized annual-type range.

Year	Fertilized with		
	None	Sulfur	Sulfur plus nitrogen
	(Pounds per acre)		
1959	692	884	2,513
1960	1,662	2,066	3,485

Note: Preliminary estimate 1961, unfertilized range, 1,500 lbs./acre.

Table 2. Composition of herbage on unfertilized and fertilized annual-type range (based on hand sorted, clipped material).

Species	Fertilizer treatment					
	1959			1960		
	None	Sulfur	Sulfur plus nitrogen	None	Sulfur	Sulfur plus nitrogen
	(Percent)					
Grasses	54.9	66.0	69.5	25.0	27.5	40.5
Grasslikes	3.3	5.0	1.6	2.0	1.2	0.0
Broadleaved herbs						
Erodium	39.3	25.5	27.1	60.9	63.7	52.1
Clover	1.2	1.2	0.5	1.6	2.9	0.1
Others	1.2	2.2	1.3	10.5	4.6	7.2
All herbs	41.7	28.9	28.9	73.0	71.2	59.4

Note: Preliminary 1961 estimate of herbage composition by foliar hit method; 54, 0, 37, 3, 6, and 46 percent, respectively.

able for winter grazing, Reppert and Duncan (1960). Animal days of grazing use obtained per acre of grazable range during the 1959 dry season were low, as expected, but proportionately greater on the sulfur-and sulfur-plus nitrogen-fertilized units than on unfertilized range (Table 3). Animal performance, too, although much lower than expected was greater from fertilized range, on both an animal and an acre basis, than from unfertilized range (Table 4).

The 1960 dry season was even shorter than that of 1959. Animals intended for the study required recuperation from prior rough handling and this held up the start of grazing until July 20. Herbage production was about normal on unfertilized range (Table 1), but herbage composition was considerably out of balance (Table 2) because of the previous fall's drought effects. The heavy proportion of broadleaved species compared to grasses in the 1960 vegetation composition was tempered somewhat by both fertilizer treatments. Grazing use in animal days, both total and per acre, was considerably above the 1959 level because more animals were available and all units produced more herbage than in 1959. Condition of the cattle at the start of the 1960 dry season affected their performance on the sulfur- and unfertilized units. Only a slight change in weight occurred on the sulfur-plus-nitrogen units. The effects of branding, castrating, and vaccinating combined with a truck ride all in one day contributed to the very poor condition of these cattle throughout the dry season.

These data for two dry seasons, one following severe growing season drought, the other after a usual growing season, indicate some of the benefits of range fertilization. Sulfur alone increased individual animal gain by 48 percent for the 1959 dry season, and animal gain per acre by 37 percent. Sulfur-plus-nitrogen doubled animal gain and increased gain per acre by more than six times. Compared to the sulfur-fertilized areas, sulfur-plus-nitrogen increased animal gain by 36 percent and gain per acre by 440 percent. Neither individual animal gain nor gain per acre was enough different between treatments in the 1960 dry season to warrant comment. The reason has already been cited.

Dry season, 1959, grazing use, in animal days per acre, was about 10 percent greater with sulfur-plus-nitrogen. The use on sulfur-plus-nitrogen units was 230 percent above the sulfur units. During the 1960 dry season, grazing use on the fertilized units was 60 to 190 percent more than on the unfertilized, and on the sulfur-plus-nitrogen units it was 80 percent above the sulfur units.

Green Season, 1960 and 1961

The 1960 and 1961 green seasons were very similar in total herbage production but very unlike in herbage composition. Because of the fall 1959 drought, 1960 was a "filaree" year. Broadleaved herbs were very abundant, with *Erodium* spp. (filaree) composing a high percent-

Table 3. Livestock grazing use in animal days on unfertilized and fertilized annual-type range by seasons.

Item	Fertilizer treatment								
	None			Sulfur			Sulfur plus nitrogen		
	1959	1960	1961	1959	1960	1961	1959	1960	1961
Dry season ranges:									
Acres grazed	130.5	130.5	.....	58.9	58.9	.....	54.5	54.5	.....
Total animal days	1,020	2,573	.....	502	1,870	.....	1,530	3,123	.....
Animal days/acre	7.8	19.7	.....	8.5	31.7	.....	28.1	57.3	.....
Green season ranges:									
Acres grazed	.....	141.3	141.3	.....	50.4	50.4	.....	52.6	52.6
Total animal days	.....	2,876	3,410	.....	2,043	2,187	.....	3,514	2,648
Animal days/acre	.....	20.4	24.1	.....	40.5	43.4	.....	66.8	50.3

Table 4. Pounds of animal gain produced on unfertilized and fertilized annual-type range by seasons.

Item	Fertilizer treatment								
	None			Sulfur			Sulfur plus nitrogen		
	1959	1960	1961	1959	1960	1961	1959	1960	1961
Dry season ranges:									
Total	787	−40	.....	486	−156	.....	2,429	47	.....
Avg./animal	66	− 2	.....	97	− 9	.....	132	3	.....
Avg./acre	6	−0.3	.....	8	−2.6	.....	45	0.8	.....
Green season ranges:									
Total	.....	4,558	8,167	.....	3,294	5,477	.....	5,665	5,690
Av./animal	.....	191	213	.....	165	205	.....	209	220
Avg./acre	.....	32.3	57.8	.....	65.3	108.6	.....	107.7	108.2

age of the herbage in this group (Table 2). Grasses made up half or less of their usual composition in the herbage. This shift in composition shortened the 1960 green season and, as already indicated, reduced the value of annual-type ranges for dry season grazing. Both of the fertilizers tended to cushion the effect—forbs were considerably less abundant and the grasses more abundant on the fertilized than on the unfertilized units (Table 2).

The effects of the fertilizers were very noticeable in terms of grazing use and weight of animal gain produced. In 1960 grazing use per acre on the sulfur units was nearly double, on the sulfur-plus-nitrogen units more than three times that of the unfertilized units. Use on the sulfur-plus-nitrogen units was 65 percent more than the use on the sulfur units that year. During the 1961 green season the same trend held but was somewhat scaled down. Use per acre on the sulfur units was up 80 percent; on the sulfur-plus-nitrogen units, 108 percent over the unfertilized units. Sulfur-plus-nitrogen units gave only 16 percent more grazing per acre than sulfur alone during 1961, the second green season after fertilization.

Livestock gains per acre on fertilized range held almost exactly the same advantages over the unfertilized as did grazing use. Gains per acre in 1960 on the sulfur and sulfur-plus-nitrogen units were 102 and 233 percent greater than on the unfertilized units. The sulfur-plus-nitrogen acres produced 65 percent more than the sulfur-fertilized acres. In the 1961 green season, animal weight production per acre was even for the two fertilizer treatments and 87 percent above production from the unfertilized acres.

Conclusions

The experience reviewed and data presented indicate rather conclusively that range herbage production, grazing use, and weight gains of grazing animals can be effectively increased on California annual-type range by fertilization. The greatest benefits came from the application of 60 pounds of sulfur and 80 pounds of nitrogen per acre. Sulfur alone, 60 pounds per acre, was less beneficial.

The benefits of sulfur-nitrogen fertilization were evident in the dry season as well as in the green season and in drought as well as in normal years. This fertilizer minimized the effects of weather on vegetation composition. It also induced earlier plant growth and sustained growth at a more rapid rate during winter when temperatures are minimal. Range livestock operators in the annual type can well afford to take advantage of a fertilizer program for greater production.

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