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PLANT, LIVESTOCK, AND ECONOMIC RESPONSES TO SELECTIVE FERTILIZATION OF SIERRA FOOTHILL RANGELAND WITH NITROGEN, PHOSPHORUS AND SULFUR

U.C. Sierra Foothill Range Field Station

C. A. Raguse, J. L. Hull, M. B. Jones, J. G. Morris, M. R. George, K. D. Olson, K. L. Taggard, and R. R. Delmas[1]

ABSTRACT

Field scale treatments of nitrogen-only, phosphorus plus sulfur, and all three elements together were aerially applied in early October of 1982 on a 520-acre site at the UC Sierra Foothill Range Field Station, and the experiment was conducted for three consecutive years without additional fertility adjustment. Seasonal (late November to late May) grazing was done with stocker steers and heifers weighed initially and at either 4-week or 3-week intervals throughout the season. Esophageal-fistulated animals were used to collect forage samples from which treatment and season related changes in quality could be assessed. An initial assessment of soil nutrient status was made and climatic data, especially precipitation and temperature, were used as aids in interpretation of results.

The significant general results of this experiment were as follows:

1. The best animal gains were from the multiple-element (NPS) and the higher-level PS treatments. This was in part a reflection of the higher stocking rates used in those treatments.

2. In spite of similar levels of grazing pressure (units of animal weight per unit weight of available forage) across

[1]Professor, Agronomy and Range Science (UC Davis); Specialist, Animal Science (UC Davis); Professor, Agronomy and Range Science (UC Hopland Field Station); Professor, Animal Science (UC Davis); Cooperative Extension Specialist, Range Science (UC Davis); Associate Professor, Agriculture and Applied Economics (Univ. of Minnesota); Plant Ecologist, Agronomy and Range Science (UC Davis); Farm Advisor (Modoc County).

treatments, average daily gains were higher for fertilized fields, indicating benefits of fertilization to forage quality.

3. The amount of rain occurring during the first year (approximately 44 inches) probably reduced plant responses to fertilization in the second and third years.

4. An extremely important element in recovery of fertilization benefits was properly adjusted stocking rates. In practice, this may require one or more within-season increases in stocking rates and close attention to phenological progress of plant development.

INTRODUCTION

Research oriented to improving the productivity of California's versions of the so-called Mediterranean climate annual rangeland has been conducted for over a half century. From this long-term effort flowed the development and application of, as examples, vegetation-type conversion (most often by employing control burns)(Arnold et al., 1951; Heady and Pitt, 1979); "re-seeding" with introduced species of annual legumes (Jones and Love, 1945; Murphy et al., 1973); concurrent correction of major soil nutrient deficiencies (notably nitrogen, phosphorus and sulfur) (Jones, 1974; Martin and Berry, 1970); and controlled grazing (Bentley and Talbot, 1951; Heady, 1961; Hormay, 1944).

Objectives of the Experiments

Beyond climatic constraints (e.g., with winter-growing annuals the amount and seasonal timing of rainfall is critical to the initiation and sustained growth of forage), the next most-limiting factor probably is plant nutrition.

This experiment was designed to provide information in three areas:

a. The current economic feasibility of fertilizing annual rangeland with selected combinations of nitrogen, phosphorus and sulfur where soils are limiting in all three elements.

b. Responses of a grass-clover-filaree annual range-plant community subjected to differential fertilization, with nitrogen alone, phosphorus plus sulfur and all three elements together.

c. Relationship of stocker steer average daily gain to level of forage on offer, time of season and species composition.

The experiment accounted for three consecutive seasons of grazing at known levels of grazing pressure which were equalized across treatments.

MATERIALS AND METHODS

These experiments were conducted at the University of California's Sierra Foothill Range Field Station, Browns Valley, Yuba County, on a site of approximately 1,000 feet elevation, with latitude and longitude approximately 39°14" N, 121°18", respectively. This location, which is representative of the lower-foothill oak woodland zone of the northern Sierra Nevada, receives an average 30-35 inches of rainfall (snowfall is very rare and transient) between mid-October and late April in a typical Mediterranean climate. Herbaceous vegetation is almost completely annual, a variable mixture of grasses, legumes and other forbs. Soils are mainly of the Sobrante and Las Posas series with smaller amounts of Auburn and Argonaut (Herbert and Begg, 1969), i.e., mostly fine to fine-loamy, mixed, thermic Mollic Haploxeralfs or Typic Rhodoxeralfs (Alfisols).

The site had been completely converted from an oak woodland with shrub understory by herbicidal killing of the oaks (1961-63) followed by a control burn in 1968. It subsequently was divided into 16 fields of roughly equal size (33 ac). Reseeding was done using a mixture of subterranean (*Trifolium subterraneum* L.) and rose (*T. hirtum* L.) clovers during the period 1971-1974. Various range utilization and livestock management experiments employing beef cattle have been conducted since that time, using conventional seasonal grazing procedures.

Experimental Design

Fertilizer treatments, main fields. The 16 fields were used for two replications of seven fertilizer treatments, as follows:

1. Control (each replication is a mean of two fields)
2. 40 lb/ac N
3. 80 lb/ac N
4. 40 lb/ac N, 30 lb/ac P, 33 lb/ac S
5. 80 lb/ac N, 30 lb/ac P, 33 lb/ac S
6. - - - 30 lb/ac P, 33 lb/ac S
7. - - - 60 lb/ac P, 66 lb/ac S

Nitrogen was applied as urea; phosphorus and sulfur as a mixture of 0-20-0-12S and 0-25-0-10S. These materials were separately applied by helicopter on October 5 and 6, 1982. The experiment was designed to run for three years to allow determination of nitrogen carryover and fertilization effects on plant species composition. Preliminary soil tests, field plots at eight locations, and a greenhouse pot experiment using soil from the eight plot sites had previously established initial conditions of soil fertility and plant (grass and legume) responses to applied nitrogen, phosphorus and sulfur, showing that all three major nutrients (N,P,S) were needed for optimal forage production on these soils.

Grazing regime. Beginning mid- to late-November, each field (replication) was uniformly set-stocked with steers (initial weight, 450-550 lb) at about 4 ac per steer. Subsequent changes in stocking rates were based on forage levels measured along permanent transects in each field and were increased twice each season, to a maximum of about 1 ac per animal. Heifers were also used for part of the stocking rate increases. When forage quality declined to where zero gain could be estimated from previous weighings, the grazing season was terminated.

SELECTED RESULTS

Climate

A particularly important determinant of total forage production and its intra-seasonal distribution is the total amount and intra-seasonal distribution of rainfall. Figure 1 shows that the 1982-83 season had a long growth period, with ample rainfall well distributed, and very good weather conditions in late spring. One positive effect was a dramatic response of the resident population of annual legumes to the phosphorus-sulfur treatments. On the negative side, earlier work by Martin and Berry (1970) and others showed that such rainfall amounts sharply reduce the carryover, or second year, response from applied nitrogen. Years two and three were characterized by successively declining rainfall amounts which, however, were well distributed within each season.

Plant

Figure 2 shows forage levels as measured across each grazing season. Only in the first year was a definite fall accumulation of growth apparent. Forage levels changed little until early March, at which time the spring "grand period of growth" began. The very high growth rates characteristic of this season (George et al., 1985) were reduced by upward adjustments in stocking rate, yet at no time during the three years was animal demand sufficiently greater than plant growth rate to alter the general nature of the seasonal production curve. The extent of potential disparity between plant growth and animal intake is illustrated by the greater forage accumulations for the phosphorus-sulfur treatments in the first year, where unintentional but significant understocking did occur.

Fall-winter levels of forage were lowest in year two, spring levels were lowest in year three. Apart from the expectation of declining forage productivity as applied nutrients were used in plant growth or leached away, long-term effects on plant productivity of higher stocking levels such as employed in this experiment have not been researched. The experiment is being continued for two additional years as an aid in determining these effects.

Per Animal Gains

Figure 2 also shows season-long patterns of stocker average daily gains (ADG). In general, these seasonal response curves can be separated into three distinct phases. First, a late-fall and winter segment, with gains rising linearly as forage amount and quality increased, and as decreasing environmental stress (cold, wet weather) acted positively at the animal level. Second, a peak, or actual plateau occurred where, on the average, rates of body weight gain of the stocker steers and heifers was at a maximum and adequacy of forage quantity and quality (especially energy content) allowed an opportunity for the animals to select a nutritious diet. Third, a brief and precipitous decline occurred as forage matured and rapidly lost its palatability (with the notable exception of subclover) and nutritional value. Also, increasing size of animals and initial occurrences of hot-weather related animal stresses may have contributed to this rapid decline in ADG. At this time in any year, animal expression of forage preference is very strongly evident and the opportunity for spatial control of forage utilization is virtually eliminated since animals tend to only graze those areas where the preferred plants are growing.

Per Acre Gains

Figure 3 shows liveweight gains per acre for the six fertilizer treatments and controls for the three individual years of the experiment. The largest treatment differences occurred during the first year. Within treatments, gains were largest for the nitrogen-phosphorus-sulfur combination, which also had the highest stocking rate. Under the conditions of this experiment (high rainfall during the first year) the 80 lb rate of nitrogen did not provide a sufficiently greater response over the 40 lb rate to justify additional cost of the treatment (see also the economic analysis below). The higher of the two phosphorus-sulfur treatments had a profound growth enhancement effect on the resident annual legumes. This treatment was inadvertently understocked during the first (1982-83) year and the measured liveweight gain underestimated the conversion potential which actually existed.

Second-year gain responses were similar for all treatments, in part reflecting the previous high-rainfall season. Treatments including P and S tended to have higher gains. In the third year, the two NPS and the higher PS treatments were highest; in fact, the 60P66S response exceeded all other treatments. In contrast, the 30P33S treatment did not differ from the control.

A further point of interest from individual-year comparisons is that they can be grouped arbitrarily in three categories, as livestock gain thresholds of 100, 150 and 200 lb/ac/year. Cleared range with a legume component together with good management and with or without some fertilization should easily produce a hundredweight of gain per acre in an average to good growing season. To attain the 150- to 200-lb threshold required higher fertility levels and addition of all three elements (in the case of 60P66S, nitrogen provided through symbiotic fixation by the PS stimulated legumes). It is noteworthy that the higher PS treatment was the only one in which the 150-lb gain threshold was reached in the third year.

Figure 4 shows the liveweight per acre gains averaged for the three years. Best gains were from the two NPS treatments (no difference between 40 and 80 N) and the higher PS treatment. In comparison, nitrogen alone, or an inadequate level of phosphorus and sulfur, did not result in three-year average gains different from the controls.

Forage Analysis

Each year, when plant growth, plant quality, and livestock performance (as measured by average daily gains) were at optimum, samples of the three principal forage classes (grasses, filaree, and clovers) were taken along permanent line transects in all fields. Table 1 presents data from laboratory analyses of nitrogen and phosphorus for samples collected on April 1, 1983.

Table 1. Percent nitrogen and phosphorus of field-collected samples of resident grasses and filaree, and seeded clovers. Values are means of 40 samples per field and of two replications per treatment.

	Nitrogen			Phosphorus		
Treatment	Grass	Filaree	Clover	Grass	Filaree	Clover
	%	%	%	%	%	%
Control	2.4	1.6	3.0	0.35	0.26	0.27
40N	2.9	1.8	2.9	0.39	0.29	0.34
80N	2.9	1.8	2.9	0.38	0.27	0.29
40N+30P33S	2.5	1.6	3.2	0.43	0.33	0.37
80N+30P33S	3.0	1.7	3.2	0.47	0.34	0.42
30P33S	2.4	1.6	4.0	0.35	0.35	0.40
60P66S	2.7	1.7	4.2	0.44	0.40	0.43
Controls + N	2.7	1.7	2.9	0.37	0.27	0.30
NPS+PS	2.6	1.7	3.6	0.42	0.36	0.40

Nitrogen content of clover tended to be higher where P and S were applied, but results for grass and filaree were not consistent. Phosphorus contents of all three groups of plants were higher where P and S were applied than for either control or N-only treatments.

Preliminary analyses for sulfur (60P66S and control, one replication for each) gave values of 0.34, 0.20 and 0.33 for the PS fertilized grass, filaree and clover, respectively. Comparable values for filaree and clover in the control were 0.16 and 0.19 (a sufficient number of grass samples has not been analyzed to date to state a value).

Table 2 shows organic matter digestibility of forage samples collected using esophageal fistulated steers. Because sample collection by this means was limited, only control, 80N, 80N30P33S and 60P66S treatments were evaluated.

Table 2. Percent organic matter digestibility of esophageal fistula-collected samples from selected treatments.

	Control	80 N	80 N 30P33S	60P66S
	%	%	%	%
January	63.6	68.4	70.1	68.8
February	64.6	73.0	71.0	73.2
March	65.8	71.8	71.8	74.7
April	64.9	68.8	69.4	72.6
May	53.0	61.8	66.9	61.4
June	59.9	50.5	53.2	52.2
July	55.2	57.6	58.4	54.2
Column Mean	61.0	64.6	65.8	65.3
Column SD	5.11	8.27	7.18	9.37
Column CV	8%	13%	11%	14%
Jan-April Mean	64.7	70.5	70.6	72.3
Jan-April SD	0.91	2.25	1.05	2.51
Jan-April CV	1%	3%	1%	3%

While the differences between values obtained were not large, they do establish that animals selected forage of higher quality from the fertilized fields. If the comparison was made for the period January through April the difference was more pronounced and also suggested a legume effect from the 60P66S treatment. Analyses also were made for percentages of nitrogen, dry matter digestibility, and organic matter content. Results from these tests were similar to those in Table 2, showing forage to be of higher quality from the fertilized fields.

Economics

Table 3 gives an economic analysis of the results, summed successively for the three years. Important variables in determining whether a given treatment proved profitable were: initial cost of treatment, level of PS-only treatments, stocking rate adjustments, and the general legume-enhancement response to the phosphorus-sulfur treatment. Clearly, nitrogen, phosphorus and sulfur all needed to be supplied, with nitrogen provided either directly or through symbiotic fixation by PS-enhanced annual legumes.

Table 3. Preliminary economic analysis of liveweight gain responses from selected combinations of nitrogen, phosphorus and sulfur applied to cleared Sierra Nevada foothill annual legume-seeded rangeland.

Treatment	Gross income/ac			Treatment cost	Gross income per acre above control treatment		
	1982-83	1983-84	1984-85		1982-83	1982-84	1982-85
lb/ac		$/ac		$/ac		$/ac	
Control	50.28	47.71	69.65	.00	.00	.00	.00
40N	64.64	52.61	59.18	16.80	-2.44	2.46	-8.00
80N	77.97	50.72	58.43	29.00	-1.31	1.71	-9.51
40N30P33S	104.28	77.02	74.25	31.90	22.10	51.41	56.01
80N30P33S	120.67	51.31	75.29	44.10	26.29	29.89	35.54
30P33S	53.80	46.07	61.39	15.00	-11.48	-13.12	-21.38
60P66S	72.23	66.51	98.45	25.45	-3.50	15.30	44.10

Note: Actual costs of fertilizers were used, plus $4.25/ac application costs ($8.50 for the NPS treatments), and interest charges at 12% for eight months. Gross income was calculated as - (No. head sold x sale wt x sale price) - (No. head purchased x purchase wt x purchase price), using prices for the dates of entry and removal from the Cottonwood Sale Yard as reported in the USDA Livestock Market News.

The similarity between the two-year and three-year summations for the NPS treatments on the one hand and the higher PS level on the other suggest that the combination of a marginal existing legume population with a large adjustment to soil phosphorus-sulfur status may have resulted in a true "enabling improvement," the positive results of which could continue for additional years.

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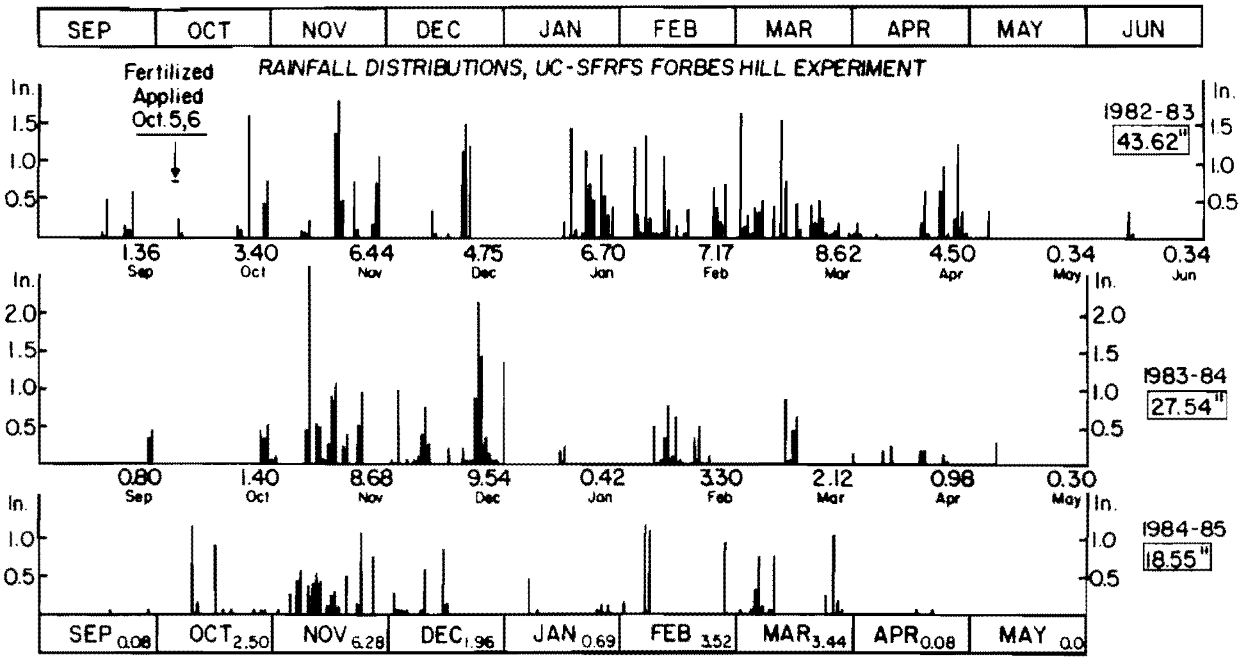

Fig. 1. Intraseasonal distribution of rainfall during the three years of the UC-SFRFS Forbes Hill experiment.

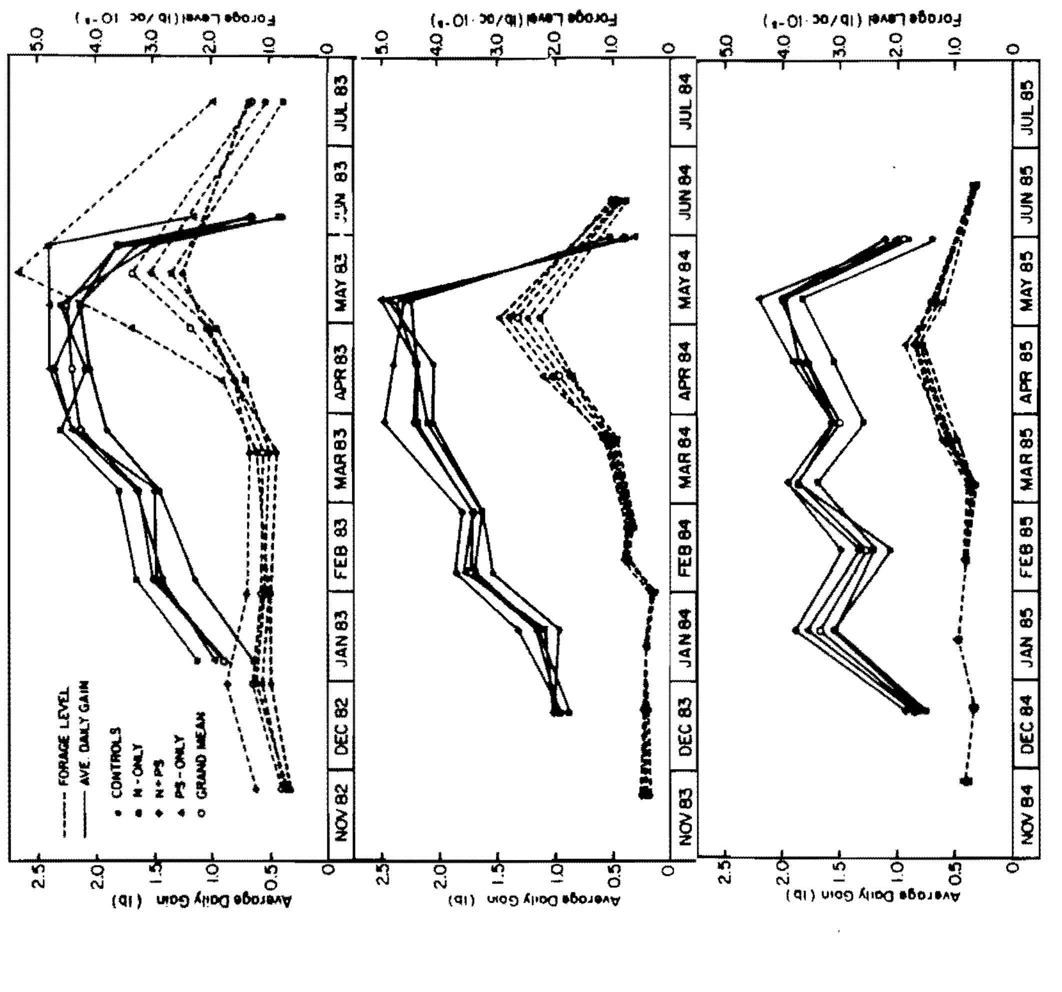

Fig. 2. Intraseasonal variations in stocker animal average daily gains and available forage for controls and three categories of fertilizer treatments during three years of the UC-SFRFS Forbes Hill experiment.

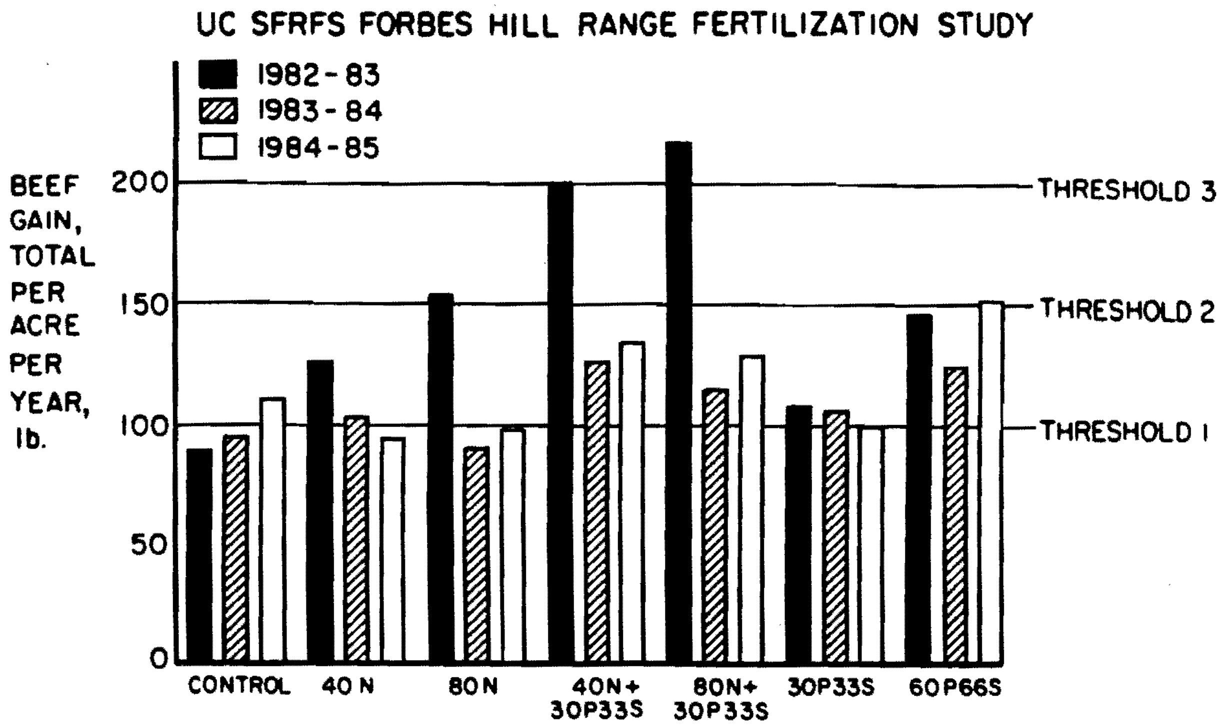

Fig. 3. Liveweight gains of beef from controls and six fertilizer treatments in each of the three years of the SFRFS Forbes Hill experiment.

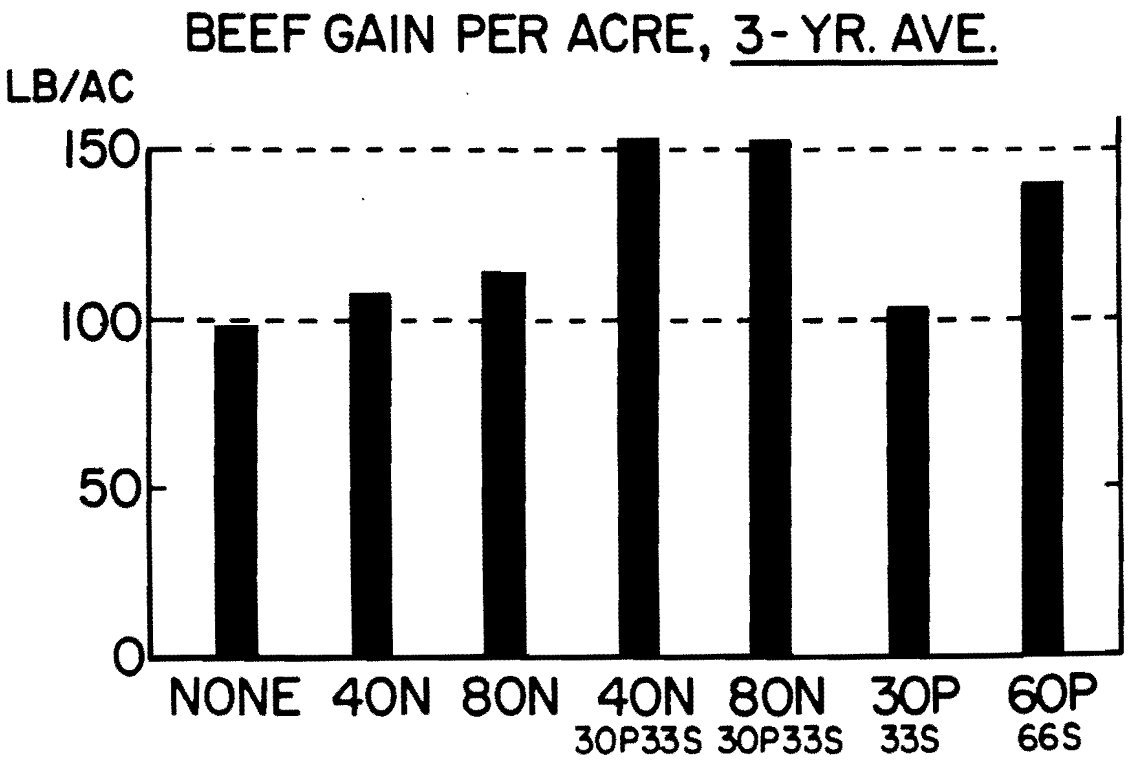

Fig. 4. Liveweight gains of beef averaged over three years for controls and six fertilizer treatments.