# Range Improvement in California by Seeding Annual Clovers, Fertilization and Grazing Management

**WILLIAM A. WILLIAMS, R. MERTON LOVE AND JOHN P. CONRAD**

*Assistant Professor and Professors of Agronomy, respectively, University of California, Davis, California*

In 1940 the Agronomy Department of the University of California began intensive investigations in range improvement. The program included testing of native and introduced species of grasses and legumes, fertilization trials and livestock manipulation.

Burle J. Jones, former Extension Agronomist, and Ben A. Madson, Professor of Agronomy, pioneered a well-organized project of adaptation trials in 40 counties of the state served by the Agricultural Extension Service. Tests were made of more than 125 species in 240 nurseries. This program continues, but after eight years of testing it was possible to draw broad lines of species adaptation (Jones and Love, 1945; Love and Jones, 1947 (revised 1952)). Bur clover (*Medicago hispida* Gaertn.), introduced into the state during the Mission period, appeared to be the most promising annual range legume on some soils in the Sacramento Valley and Sierra foothills during the early years of testing, and subclover (*Trifolium subterraneum* L.) looked good in some plots in those areas and was outstanding along the north coast.

Meanwhile in Ventura County (south coast), 1941 to 1946, sulfur applications had effected marked responses of bur clover the first year, to be followed by nearly as marked responses of grain and range forage the second and a few ensuing years (Conrad *et al.*, 1947). In consequence, about 150 exploratory trials with carriers of phosphorus, potassium and sulfur were established in 20 counties. Of the 50 tests giving good to marked responses of bur clover about 40 percent were from gypsum (carrier of sulfur), about 40 percent from treble superphosphate, and 20 percent from both. Several of the remaining sites later gave responses of bur clover when manure was applied in addition to phosphates. From a practical standpoint, however, on some reddish soils it was not possible to establish stands of bur clover even with the addition of phosphate fertilizer (Love, 1952). In 1944 rose clover (*Trifolium hirtum* All.), introduced from Turkey, was tested for the first time (Love, 1948; Love and Sumner, 1952). That year, too, several varieties of crimson clover (*Trifolium incarnatum* L.) were also tested for the first time in dryland plots in California. These clovers succeeded amazingly well on the soils that would not support good stands and growth of bur clover.

Extensive species and fertilizer tests were conducted at the Arthur Brown Hereford Ranch, Wilton, Sacramento County, California, from 1944 to 1952 to 1952 on San Joaquin soil. This is a slightly acid, shallow soil, 2.5 feet to hardpan, and was derived from granite alluvium. It had been farmed for 40 years to cereal hay, finally yielding one-half to one ton every other year with a negligible amount of low quality, volunteer pasture in alternate years. These tests showed that rose, crimson and subclovers, both the Mt. Barker and Tallarook varieties, could make a significant contribution by increasing forage production and quality. It was shown that it is economically feasible, not only to seed the clovers but also to apply adequat amounts of fertilizer. The pho phated clovers yielded about 5,0( pounds of dry forage compare with 1,300 pounds per acre on tl unimproved range and about 9( pounds of protein compared wit 143 pounds per acre. Grazir trials on the 5- to 10-acre plots i dicated that about three times tl original carrying capacity coul be expected (Love, 1952).

## Methods

In the fall of 1950 a range ir provement program involving u of these annual clovers, phospha fertilization and grazing manag ment was initiated on the France chi Ranch, Lincoln, Placer Count This program resulted direct from the research work previous discussed.

This ranch is in the 20-inch a nual rainfall zone, and over 8 percent of the rain occurs durir the months of November throug March. The soil is typical of tl gently undulating terrace lar along the base of the western slo of the Sierra Nevada Mountai and is classified as Placentia gra elly loam. It is an acid sc (pH 5.7) developed from grani alluvium and contains a dense cl pan at the depth of 18 to 24 inche The land had previously been us as an annual forage range wi part of it farmed annually to oa and vetch for hay.

Fifty acres, designated as fie 1, were seeded in October, 195 prior to the fall rains, with a mi ture of rose clover, crimson clove and Mt. Barker and Tallarook su clovers. The first operation w the application of 200 pounds p acre of single superphosphate. seedbed was prepared by diskin and seed was broadcast by pla after being inoculated with the a propriate strain of legume bacter (Williams, Lenz, and Murph 1954). The final operation w ringrolling to cover the seed an firm the seedbed. Field 2 and fie 3 were seeded by the same pr cedure in the fall of 1951. In 19 an additional 130 acres in field were seeded with a homegrow

mixture of rose clover and crimson clover to which Mt. Barker and Tallarook subclovers were added.

In 1952 a field on the adjacent Chamberlain Ranch was seeded by air to a mixture of the same species without seedbed preparation. The seeding and fertilization rates used in these fields are summarized in Table 1.

In each field numerous strips were left unfertilized as checks. In order to obtain a measure of forage production, botanical composition and feeding value, approximately 24 paired one-square-foot quadrats were harvested from each field in two successive years and botanically separated by hand. Field 1 was not included in this series of measurements because it was nearing the end of a grazing period at the time the quadrats were harvested.

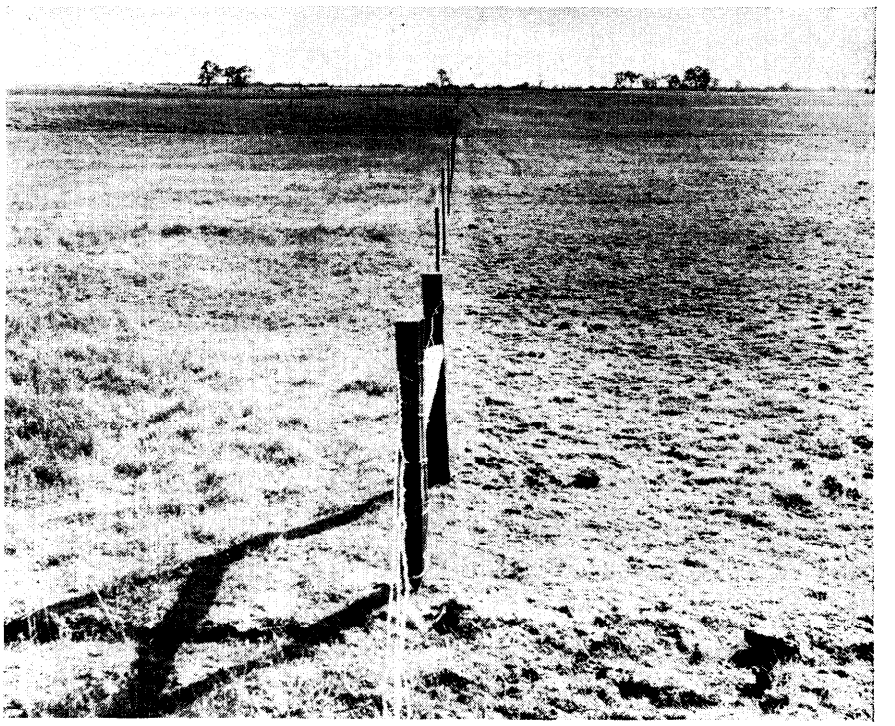

FIGURE 1. The cows have been turned into field 3, east half (*left*), after being in field 3, west half (*right*) since September 4, 1953. Photo was taken December 1, 1953. The difference in cover indicates the ready utilization of the dry clovers by beef cattle, as the whole field was seeded and fertilized with 200 pounds of single superphosphate per acre in fall 1951.

## Results and Discussion

### Grazing Capacity

Since this range improvement program is part of a commercial cattle operation, an important part of the information obtained is in terms of grazing capacity. Detailed records were kept of the number of head and dates turned in and out of the various pastures. This is particularly important in correlating the forage research information obtained from quadrat yields with the final test of the grazing animal.

On March 20, 1951, 50 Hereford cows with their calves were turned into field 1 which had been seeded the previous September. The clovers were getting ahead of them so an additional 100 head with their calves were turned in on April 1. When the animals were removed on April 30 there was still an abundance of feed left so that later a small seed crop of about 20 pounds per acre of rose and crimson clovers was "combined". (The subclovers set seed too low to be harvested in this manner.) In addition, from June 10 to July 1, 100 head in an adjacent irrigated pasture had free access to the 50 acres of dry clover and native grass. The cost of the seed, fertilizer and seeding operations that year was about $20 per acre. This investment was more than returned the first season. In 1952, 50 cows and their calves were carried in field 1 from March 9 to May 20 and 100 cows with their calves from May 20 to June 10. In 1953, 60 cows with their calves were turned in on February 15. Fifteen cows were removed March 10, the remainder staying on until May 22 when they were turned onto irrigated pasture, but allowed access to field 1 until June 15. The carrying capacity calculated without allowance for the grazing which was supplementary to the irrigated pasture was 3.30 animal unit months per acre in 1951, 3.47 in 1952, and 3.10 in 1953. This may be compared to the grazing capacity of 1.00 animal unit months per acre in 1950, the year prior to improvement, when 25 cows were carried two months in this field.

With the improvement program well under way, feed was plentiful enough so that fields 2 and 3 were not grazed to capacity in 1952 and 1953. During the spring of 1953

**Table 1. Synopsis of seed mixtures and fertilization of four fields on the Franceschi ranch (numbered) and one field on the Chamberlain ranch, Lincoln, Placer County, California.**

| Field | Acreage | Seed Mixture | | | | Rate of superphosphate applied | Date of seeding and fertilizer applications |
|---|---|---|---|---|---|---|---|
| | | Rose clover | Crimson clover | Mt. Barker subclover | Tallarook subclover | | |
| | | (*lbs./acre*) | | | | (*lbs./acre*) | |
| 1 | 50 | 3 | 3 | 1½ | 1½ | 200 | Oct. 1950 |
| 2 | 68 | 3 | 3 | 1½ | 1½ | 200 | Oct. 1951 |
| 3 | 210 | 3 | 3 | 1½ | 1½ | 200 | Oct. 1951 |
| 4 | 130 | 2 | 4 | 2 | 2 | 150* | Oct. 1952 |
| Chamberlain | 30 | 3 | 3 | 2 | 2 | 150 | Oct. 1952 |
| | | | | | | 300 | Oct. 1953** |

*Treble superphosphate.
**Fertilizer application only.

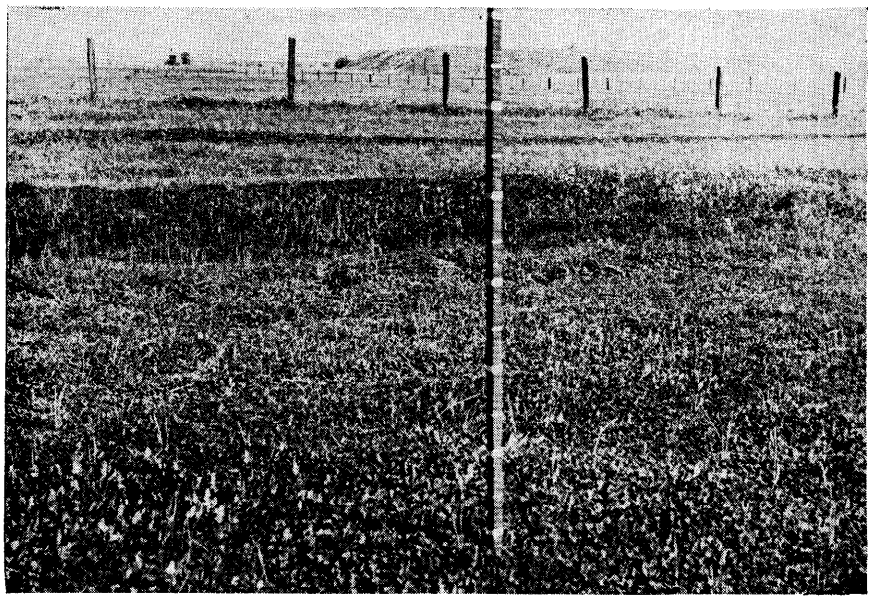

FIGURE 2. Response of seeded annual clovers to the application of phosphate fertilizer (dark strips). Photo was taken March 30, 1953 in field 3 after 40 days without rain.

field 2 was subjected to a short period of heavy grazing by 60 cows from March 10 to April 17.

Grazing was deferred on field 3 for fall dry feed and to permit a seed crop to be taken in both 1952 and 1953. Grazing use in 1952 was 105 cows from September 4 to December 8 or 1.58 animal unit months per acre after 13,000 pounds of crimson and rose clover seed had been produced. The dry feed was supplemented with one pound of cottonseed cake per head per day during the last week of grazing since the feed had been rained on by then. Early in 1953 the field was cross fenced and 105 acres produced a harvested seed crop followed by fall grazing by 85 cows from September 4 to December 1, or 2.27 animal unit months per acre. The other half was grazed lightly in the spring of 1953, seed was harvested in June, and the 85 cows were turned in on December 1 to utilize the stubble. Beef cattle utilize this dry feed to good advantage (Fig. 1).

### Effect of Phosphate Fertilizer on Forage Production

Quadrats harvested during the period May 22-27, 1953, show the effect of the phosphate fertilizer on forage production, botanical composition and feeding value of the seeded range. The clovers were mature at that time with about half the heads shattering when gently hand threshed. The fertilizer had a very striking effect on dry matter production (Table 2 and Figure 2). The clovers in fields 2 and 3 were volunteer stands resulting from natural reseeding from the 1951-52 crop. The data for field 2 show the effect of fertilizer on recovery after it was grazed by 60 cows from March 10 to April 17, a grazing use of 1.12 animal unit months. There was less than a half ton of dry forage aftermath on the unfertilized strips compared with more than 1.6 tons on the fertilized areas.

Field 4 and the Chamberlain field were seeded in the fall of 1952 and grazing on both was deferred for dry feed in 1953. The forage production on field 4 when fertilized was over six times that of the check strips. The production in the Chamberlain field, although showing a highly significant response to fertilization, did not increase as much as field 4 because of the lack of seedbed preparation and the resulting poorer initial legume stand as indicated by the botanical separation data in Table 3. Nevertheless, the results were gratifying because the establishment of adequate stands without disturbing the sod eliminates the hazard of erosion, and stock are able to graze the fields during wet weather with less deterioration of the stand and soil structure than when a seedbed is prepared.

### Botanical Composition

At the time the 1953 quadrats were harvested the forage was separated as rose clover, crimson clover, subclover and resident annuals. The latter group consisted mainly of broad-leaf filaree (*Erodium botrys* Bertol.), wild oats (*Avena fatua* L.), and soft chess (*Bromus mollis* L.). In all four fields the fertilizer increased the

**Table 2. Effect of phosphorus fertilization on forage production on range seeded with annual clovers.**

| Field and Treatment | Dry Forage Harvested May 22-27, 1953 | Dry Forage Harvested May 17-20, 1954 |
|---|---|---|
| | *lbs./acre* | |
| *Seeded and Fertilized Fall 1951* | | |
| Field 2 | | |
| Check | 880 | 990 |
| 200 lbs./A superphosphate | 3,280** | 4,490** |
| Field 3 | | |
| Check | 2,370 | 1,970 |
| 200 lbs./A superphosphate | 4,360** | 3,420** |
| *Seeded and Fertilized Fall 1952* | | |
| Field 4 | | |
| Check | 660 | 860 |
| 150 lbs./A treble superphosphate | 4,190** | 2,850** |
| Chamberlain | | |
| Check | 850 | 1,740** |
| 150 lbs./A superphosphate* | 2,180** | 4,390** |

*Additional 300 pounds of superphosphate per acre applied in fall 1953.
**Difference significant at 1% level.

**Table 3. Effect of phosphorus fertilization on the botanical composition of forage on range seeded with annual clovers.**

| Field and Treatment | Botanical Composition | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Harvested May 22-27, 1953 | | | | Harvested May 17-20, 1954 | | | |
| | Rose clover | Crimson clover | Sub-clover | Resident Annuals | Rose clover | Crimson clover | Sub-clover | Resident Annuals |
| | —%— | | | | —%— | | | |
| *Seeded and Fertilized Fall 1951* | | | | | | | | |
| Field 2 | | | | | | | | |
| Check | 16 | 3 | 5 | 76 | 35 | 0 | 1 | 64 |
| 200 lbs./A superphosphate | 44 | 20 | 10 | 26 | 62 | 0 | 13 | 25 |
| Field 3 | | | | | | | | |
| Check | 61 | 22 | 2 | 15 | 44 | 4 | 0 | 52 |
| 200 lbs./A superphosphate | 68 | 22 | 1 | 9 | 57 | 12 | 0 | 31 |
| *Seeded and Fertilized Fall 1952* | | | | | | | | |
| Field 4 | | | | | | | | |
| Check | 28 | 16 | 5 | 51 | 31 | 8 | 12 | 49 |
| 150 lbs./A treble superphosphate | 26 | 59 | 4 | 11 | 8 | 58 | 6 | 28 |
| Chamberlain | | | | | | | | |
| Check | 22 | 4 | 2 | 72 | 69 | 2 | 1 | 28 |
| 200 lbs./A superphosphate* | 36 | 9 | 2 | 53 | 71 | 12 | 0 | 17 |

*Additional 300 lbs./A of superphosphate applied in Fall 1953.

proportion of seeded legumes in the forage at the expense of the resident annuals. This can readily be seen in Table 3 in the columns titled "Resident Annuals". Similar increases have been obtained in the growth of resident legumes on California and Oregon ranges by Conrad (1950 and 1951), Conrad *et al.* (1947), Bentley and Green (1954) and Cooper and Sawyer (1955), using phosphorus and sulfur fertilizers.

Under conditions of low fertility rose clover was the dominant legume in all four fields. In fields 2, 3 and the Chamberlain field, the percentage of rose clover was further increased by fertilization at the expense of the resident annuals. Fertilization increased the proportion of crimson clover in all fields except field 3 where the proportion remained unchanged but still increased in absolute production since total forage increased. In field 4 crimson clover became dominant with fertilization because this seed mixture contained twice as much crimson clover as rose clover. Crimson clover did not make a very strong initial showing in the Chamberlain field where no seedbed was prepared.

Subclover was present in minor amounts irrespective of fertilization in fields 3 and 4, and the Chamberlain field. The difference in growth habit between the prostrate subclover and the upright rose and crimson clovers placed the subclover at a disadvantage under the management program in those fields involving deferred grazing and seed harvesting. In field 2, subjected to moderate spring grazing, subclover made more of a showing where fertilized.

An additional series of quadrats was harvested on May 17-20, 1954, from sites comparable to the 1953 series. Yields of forage were again markedly increased by the phosphorus fertilizer even though no reapplication was made during this season except on the Chamberlain field, which received 300 pounds per acre of single superphosphate in 1953 in addition to the initial 150 pounds applied in 1952. Forage production was much improved in the Chamberlain field over that of the previous year. It is of considerable interest to note that this field, seeded in sod, was fully as productive in the second year as field 4, seeded at the same time but on a prepared seedbed.

Yields on the fertilized strips on field 3 and 4 were less than in 1953, since both were grazed early in 1954 and the harvested quadrats were a measure of recovery. Grazing on field 2 and the Chamberlain field was deferred for dry feed in 1954.

The botanical composition data for 1954 are not quite as accurate as those for 1953 since the samples dried somewhat before the separations could be completed, and some shattering resulted. However, several trends are evident. Crimson clover was reduced in field 2 and 3 and remained substantially unchanged on the fertilized areas of field 4 and the Chamberlain field. This seems to be related to the age of the stand. Rose clover was very competitive in the Chamberlain field where it amounted to 69 and 71 percent of the forage in the check and fertilized treatments re-

**Table 4. The effect of phosphorus fertilization on the composition (dry basis) of forage on range seeded with annual clovers (May 22-27, 1953 harvest). Average of all fields.**

| Forage | Treatment | Protein | Fiber | Fat | Ash | N Free Extract | Phosphorus | Calcium |
|---|---|---|---|---|---|---|---|---|
| | | | | | —%— | | | |
| Clovers | Check | 12.1 | 30.6 | 1.7 | 5.5 | 49.6 | .098 | 1.37 |
| | Fert. | 14.3 | 30.8 | 1.7 | 4.9 | 48.5 | .144 | 1.37 |
| Resident annuals | Check | 6.6 | 30.0 | 1.9 | 6.9 | 54.6 | .103 | 1.56 |
| | Fert. | 8.2 | 29.2 | 1.8 | 7.1 | 53.7 | .120 | 1.58 |
| Total feed | Check | 9.0 | 30.6 | 1.8 | 6.2 | 52.5 | .099 | 1.46 |
| | Fert. | 13.1 | 30.6 | 1.6 | 5.3 | 49.4 | .136 | 1.40 |

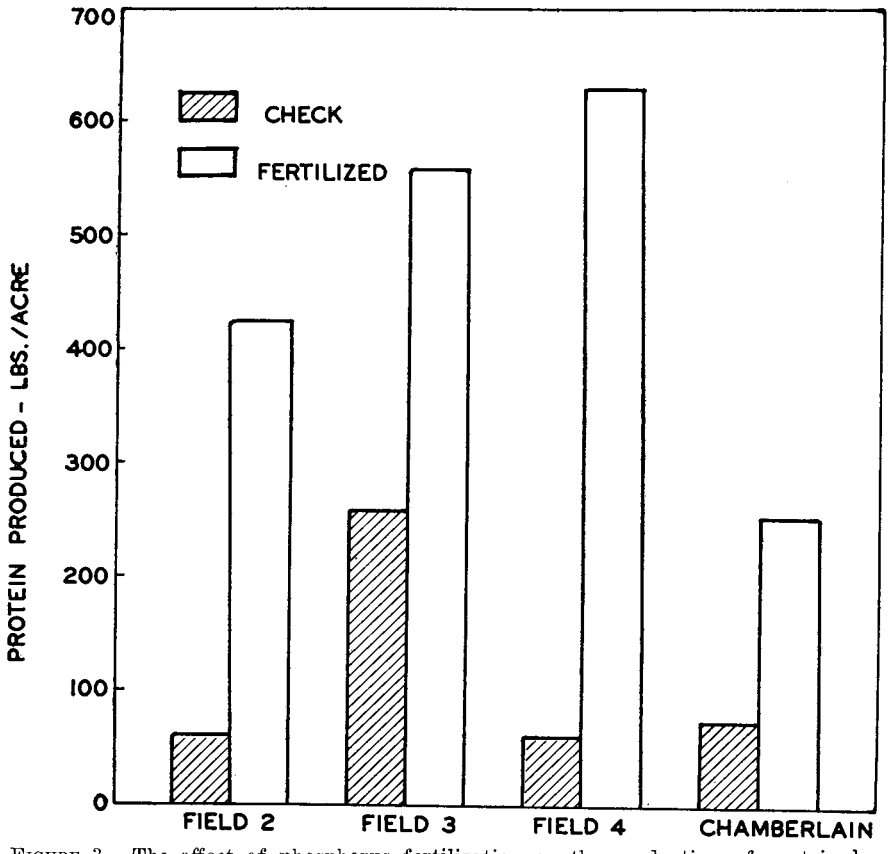


FIGURE 3. The effect of phosphorus fertilization on the production of protein by range seeded with annual clovers (harvested May 22-27, 1953). Fields 2 and 3 received 200 pounds of single superphosphate in the fall 1951; field 4, 150 pounds of treble superphosphate, and the Chamberlain field 150 pounds of single superphosphate per acre in the fall 1952.

spectively, a large increase over the previous year.

**Forage Quality**

The feed composition of the 1953 quadrat samples was analyzed by species. The average composition for each field and treatment was weighted by the proportion accounted for by each of the botanical separates. In every field crude protein was increased. The phosphorus-fertilized areas averaged 13.1 percent protein compared to 9.0 percent for the check treatment (Table 4). This highly significant effect is a contrast to the results of application of nitrogen and phosphorus fertilizer (16-20-0) to native range by Hoglund, Miller, and Hafenrichter (1952) which caused a slight decrease in the percentage of protein, apparently the result of stimulation of non-legumes by the nitrogen.

The importance of the increase in protein is emphasized when it is considered with the increased forage production resulting from fertilization. Total protein per acre was increased from two times in field 3 to nine times in field 4 (Fig. 3). This increase in production of the protein fraction of the feed has been an important factor in increasing the grazing capacity of this range.

The protein content of the feed was not only increased on the fertilized strips by the increased proportion of clovers, but also by the significant increase in percentage protein in the clovers (Table 4). The resident annuals also appeared to increase in protein but the difference is not statistically significant. The quality of the feed prior to the introduction of the clovers and use of fertilizer is indicated by the average composition of the unfertilized resident annuals. At the stage of maturity when sampled they were supplying a level of nutrition which would have required the addition of a protein supplement.

The values for crude fiber, fat, ash and calcium were not consistently affected by fertilization.

The phosphorus level of feed grown on this soil when unfertilized is inadequate for livestock well-being. The range improvement operations of seeding legumes and phosphorus fertilization increased the phosphorus in the feed significantly. This was in large part the result of the response of the clovers, since their phosphorus content was increased more than that of the resident annuals.

**Effect of Livestock Use**

The idea of concentrating the grazing of animals in weedy fields in the early spring to discourage the undesirable annuals and encourage the more desirable species was first suggested by Love (1944) and Jones and Love (1945). Intensive research on a private ranch, conducted over a period of eight years, served to bring out the practical aspects of this idea on arable land (Love, 1952). The work conducted on cleared and seeded brushlands confirmed the practice even further (Love and Jones, 1947).

The relative ease of establishment of seeded species in brush burns is due in no small measure to the complete lack of competition by resident herbaceous species. The relative difficulty encountered in areas with an herbaceous cover is primarily due to that cover. There can be no question but that "the better the seedbed, the better the stand." However, it is not always economical to have a clean seedbed for dryland range plantings. It might take several years of cropping or fallow, and the yields would not justify the expense. Furthermore, cultivation for two or three consecutive years would subject the soil to erosion hazards, since much of this arable rangeland is classified as Class IV land. Therefore, one is faced with the facts that (1) resident annuals are

present in most seedings, and (2) annuals develop faster than most seeded species. A heavy concentration of stock in early spring not only reduces this competition by weedy annuals but converts them into meat or wool when palatable and nutritious.

The Franceschi program began prior to initiation of the research on the ranch. It was noted, however, that field 1 was very weedy in the seeding year. Two exclosures, 12 feet square, were placed in the field. In these the clovers suffered from the severe competition of the resident annual grasses, whereas in the field a good stand of seeded clovers developed the first year. The grazing load of better than three animal-unit-months per acre in early spring favored the legumes, and the continuation of this practice for three seasons resulted in the dominance of subclover over rose and crimson clover. In the phosphated strips in fields 2, 3 and 4, which were relatively clean, deferring the grazing had no deleterious effect on the clovers.

In the unfertilized strips in fields 2 and 4, and in both the fertilized and unfertilized strips in the Chamberlain field, an early grazing during the seeding year would have been helpful to the clovers.

## Summary

A range improvement program involving the seeding of adapted clovers, phosphorus fertilization and grazing management on over 500 acres was carried out over a five-year period. Grazing records and quadrat harvests demonstrate the marked success of the improvement methods. The grazing capacity of the range was increased three-fold by the improvement of both the bulk and the quality of the feed.

The seeded legumes, rose, crimson and subclovers, were able to make better use of nutrients supplied in phosphate fertilizers than were the resident species. As a result of the improved level of fertility the clovers produced a feed high in protein and also improved the phosphorus content of the feed. Botanical composition records demonstrate the ability of a mixture of annual clovers of varying growth habit to survive and produce under a variety of grazing conditions.

Since it is almost impossible to have range land in a Mediterranean-type climate completely free of weeds before seeding, a concentrated grazing by livestock or a mowing is usually imperative the first spring.

The use of a mixture of annual clovers of varying growth habit allows much greater latitude of adjustment of livestock use than is otherwise possible.

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## THE ECOLOGY OF *Halogeton glomeratus* ON WYOMING RANGELANDS

*Abstract of thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Range Management, University of Wyoming, 1955.*

Studies were conducted during 1954 and 1955 on the ecology, anatomy and physiology of halogeton.

Anatomically, halogeton is similar to other Chenopodiaceae. The hypocotyl is characterized by an anomalous secondary thickening in which several layers of cambium are active and form concentric arcs of vascular tissue. The stem is characterized by the formation of a secondary cambium that gives rise to vascular tissue. The leaf is round in cross-section and contains accumulations of druse crystals of oxalate compounds. Two types of seed are produced—black, highly viable, mature seed and brown, immature seed of greatly reduced viability.

Ecologically, halogeton occurs where conditions exist in plant communities that allow it to supercede missing vegetation. Where ground cover of perennial grasses and shrubs was 22.5 percent or more, the amount and type of native vegetation excluded halogeton. In similar overgrazed areas in which plant cover had been depleted to 8.7 percent by overgrazing, halogeton made up nearly 50 percent of the total plant cover. However, plants such as *Elymus junceus, Malvastrum coccineum and Agropyron cristatum* in stands of 5 to 10 percent cover appeared to serve as a competitive deterrent to the invasion of halogeton. Below ground, halogeton is in direct competition with other annuals. With its relatively shallow root system, halogeton has difficulty surviving among perennial plants with vigorous root systems at comparable depths.—FRANK L. RAUCHFUSS. Wyoming Agricultural Experiment Station, Laramie, Wyoming.