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Universally, an increase in legumes on rangeland has long been associated with improvement. Herbage production is greater because of increased available nitrogen, protein content of the herbage is higher, and livestock gains are greater. California's annual-plant type fortunately has some native rangeland legumes (10) and climatic conditions which allow survival of dryland legumes from other parts of the world. Experience at the San Joaquin Experimental Range has shown that both do well on granitic soil when fertilized but that the native legumes may be a better bet in the long run.

Many native clovers (Trifolium spp.) are distributed widely throughout all but the desert regions of California. Nine of these are present at the San Joaquin Experimental Range. Three are important forage plants. With sulfur fertilization, the native clovers become dominant plants in both the range flora (3) and the cattle diet (7).

Bur clover (Medicago hispida), introduced during the Mission period of California's history, is a valuable legume which is widely adapted but grows poorly or not at all on droughty, sulfur-deficient granitic soils. More recently introduced annual clovers are also useful for improving annual-type ranges. Rose clover (Trifolium hirtum) is recommended for the drier, poorer rangeland sites, and sub clover (T. subterraneum) and crimson clover (T. incarnatum) do well on sites with better fertility and moisture conditions (11). With fertilization, these introduced species have improved herbage quality and greatly increased herbage production (1, 4, 9, 12).

Growth and herbage production of native legumes have been observed for many years on fertilized and unfertilized ranges at the San Joaquin Experimental Range. Between 1935 and 1940 production was sampled in six range pastures totaling 1,400 acres; between 1943 and 1945 on three areas totaling 560 acres; in 1948 on 400 acres; and from 1949 to 1956 on two small areas totaling 100 acres.

The Experimental Range, located near the geographical center of the State, is typical of the granite-soil section of the Sierra Nevada foothills. The Vista sandy loam slope soil averages about 1-1/2 feet in depth, and in alluvial swales the Visalia sandy loam may be as deep as 4-1/2 feet. On both these soils all vegetation responds to additions of nitrogen. Sulfur is needed to get maximum

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legume growth. In the swales a small increase in plant growth results from added phosphorus.

PRODUCTION INFLUENCED BY RAINFALL

Production of both native and introduced annual legumes was closely related to rainfall and associated soil moisture conditions. Legume production was more closely related to the distribution of adequate rain during late fall, late winter, and early spring than to total rainfall (table 1). Out of 8 years of above-average rainfall only 3 produced above-average legume crops. In 10 years of below-average rainfall, 5 were better than average legume years and 5 were poorer than average. Years with prolonged late winter or early spring droughts had low legume production even though many plants were established earlier. Even when an inch or more of rain fell in October, extended drought in November reduced legume growth. In 1949, an unusually dry year (2) with an extended drought from late March through early May, ground lupine (Lupinus bicolor) made up 10 percent of total herbage production. Total herbage production and production of legumes other than lupine were near a record low that year.

The highest level of native legume herbage production was recorded in 1938 (table 1) the year of greatest total rainfall. Other years favoring growth of legumes occurred in 1945, 1950, 1952, 1954, and 1956. Two of these--1950 and 1954--had well below average rainfall, but in both, frequency of storms prevented soil from drying for long periods during the months of active plant growth. The second best legume year, 1945, had just average precipitation, but 9 inches fell during February and March.

Warm temperatures accompanied by rainfall sufficient to keep the soil moist during October and November stimulated early germination and establishment of legumes and favored high production. However, a good fall start was nullified if rains did not materialize during the main growing season. This occurred in the 1950-51 season when exceptionally favorable fall growing conditions started rapid plant growth but dry spring weather after a cold January and February allowed only limited spring growth of legumes.

Table 1.--Total rainfall and native legume production at the San Joaquin Experimental Range (unfertilized range)

Year	Total rainfall	Average total legume	Whitetip clover	Littlehead clover	Tree clover	Total clover	Spanish clover	Ground lupine	Other legume
	Inches	Percent of total herbage							
1935	29.40	8.0	4.2	1.8	0.2	6.2	0.9	0.7	0.2
1936	22.65	2.2	0.3	0.5	0.1	0.9	1.1	0.1	0.1
1937	22.96	1.8	0.5	0.4	0.1	1.0	0.5	0.2	0.1
1938	32.09	20.0	5.3	5.1	0.5	10.9	4.9	2.9	1.3
1939	12.25	8.7	0.7	1.8	1.6	4.1	1.8	2.6	0.2
1940	21.22	5.9	0.9	0.7	0.3	1.9	0.9	1.4	1.7
1943	17.24	8.1	1.7	1.3	1.0	4.0	1.6	2.1	0.4
1944	13.79	5.1	0.8	0.5	0.5	1.8	0.9	2.2	0.2
1945	18.99	16.7	5.6	2.1	1.3	9.0	2.0	4.8	0.9
1948	14.50	7.1	0.6	0.9	0.2	1.7	0.1	3.7	1.6
1949	12.39	12.7	1/	1/	1/	1.8	0.7	10.0	.2
1950	16.00	15.2	1/	1/	1/	5.9	1.7	7.1	.5
1951	21.38	5.3	3.6	0.5	0.3	4.4	0.8	0.1	--
1952	24.69	13.4	5.1	3.0	1.7	9.8	1.8	1.7	.1
1953	15.71	7.3	4.0	0.8	0.5	5.3	1.1	0.9	--
1954	15.58	12.6	1.0	5.2	2.5	8.7	1.0	2.8	.1
1955	16.72	10.4	1.2	2.9	2.8	6.9	1.8	1.7	--
1956	26.45	12.2	3.9	2.9	2.1	8.9	2.9	0.4	--
Ave.	2/ 19.61	9.6	2.5	1.9	1.0	5.2	1.5	2.5	.4

1/ Not determined.

2/ 19.61 is the average annual rainfall for 22 consecutive seasons, 1934-35 to 1955-56 inclusive.

RESIDENT LEGUMES

Clovers are the best forage plants among the native legumes. Whitetip clover (Trifolium variegatum) in wet swales and littlehead clover (T. microcephalum) and tree clover (T. ciliatum) on the slopes are the important species although several others are present and sometimes locally abundant.

Whitetip clover (fig. 1) was the most abundant clover on unfertilized native range even though it grew only in "wet swales" which

made up less than 10 percent of the area of any range pasture. In several years when the swales were wet most of the winter and spring, more than 5 percent of the total herbage production was of this species. In years when water did not stand or flow in the swales, whitetip clover produced less than 1 percent of the herbage. Abundant or scarce, it was one of the most palatable species growing, and areas where it dominated were always closely grazed. It has a wide range in California and extends north through Oregon and Washington into British Columbia (8). In eastern Oregon it has been used for improvement of native meadow range (5). Whitetip clover has responded to sulfur fertilization in the Sierra foothills (3).

Figure 1.--Whitetip clover forms dense stands in wet swales during good rainfall years.

Littlehead clover was second most abundant on unfertilized range. It made up an average of almost 2 percent of the total range herbage. It is normally small and grows in scattered stands on slope soils. Where the range has not been fertilized with sulfur-bearing fertilizer, littlehead clover is taken by cattle as they select other desirable plants but is not singled out as is whitetip clover.

On sulfur-fertilized range, littlehead clover became vastly more prominent. Instead of the usual single-stemmed plants, 6 inches high at maturity, the clover branched freely and reached 14 inches high. The plants dominated large areas on good slope soil and their total production surpassed that of whitetip clover. In 1952 littlehead clover made up 10 percent of the total herbage on 100 acres of fertilized range. Littlehead clover was selected by cattle (7) especially on slopes. On unfertilized range heaviest grazing of littlehead occurred along the swale edges.

Tree clover, the third most important native clover, averaged about 1 percent of total herbage production and was found on the moist lower slopes bordering the "wet swales." On sulfur-fertilized range it averaged more than 2 percent of a greater herbage yield.

Two other native legumes were prominent. Spanish clover (Lotus americanus) a summer growing plant, averaged 1-1/2 percent of unfertilized range herbage production. It was grazed during the early summer when most other annuals were dry. Ground lupine (Lupinus bicolor) made up 2-1/2 percent of pasture herbage on the average but was seldom grazed. These two legumes have large root nodules and probably are active in nitrogen-fixation. Small increases in production of both species were recorded on fertilized range.

Bur clover, an introduced annual legume that has become naturalized on California annual-type range, is rather sparse on the sandy granitic soil of the Experimental Range. Its occurrence is limited to occasional obscure plants or infrequent colonies along stream banks. With fertilization on bottomland soil, however, it may become dominant. In one case along a creek in a fertilized field, it covered more than one-fourth of the bottomland soil; on an adjacent fertilized slope density was only 4 percent. Bur clover was generally moderately utilized by cattle in late winter and early spring. As the other annual herbage matured, however, bur clover was selected more often, even to a close level by the time other plants were used moderately. Often the burs remained thick on the ground after close use.

INTRODUCED LEGUMES

Several promising introduced annual legumes, mostly clovers, have been planted and compared with natives on both alluvial bottomland and slope soils. In mid-December 1951 an area previously used for other range reseeding tests was drilled at 6 pounds per acre to a mixture of perennial grasses and annual legumes. The annual legumes were planted at the following rates per acre:

Sub clover	1 pound
Bur clover	1 pound
Rose clover	2 pounds
Hairy vetch[2/]	1 pound

2/ Hairy vetch (Vicia villosa) was planted only on the bottomland soil.

Single-superphosphate at 400 pounds per acre was broadcast at time of seeding; in September of 1953, 375 pounds per acre were applied. Fertilization aimed to increase grazable legume herbage and insure legume survival. A general decline in legumes occurred after 1953 when fertilization was terminated.

Rose and Bur Clovers

Rose clover was more tolerant of the dry sites and grew higher on the slopes than any other introduced annual legume. Plant counts in 1953 (table 2) showed that rose clover was the only legume occurring in quantity on the upper slope soils. Over the years, however, there was always a trace of bur clover on the upland slope site. On the intermediate slope site, which actually contained a gradation of both slope and bottomland soils, there were five times as many rose as bur clover plants. This ratio was reversed on the bottomland soil.

Both rose and bur clover grew best on the lower deeper soils, and plant size decreased with distance up the slope. During years of favorable moisture conditions, 1954 for example, plants grew 10 to 12 inches high and formed a nearly solid ground cover. In 1953 when moisture was deficient during much of the growing season, plants on the same spot were only 2 or 3 inches high and density was low (fig. 2).

Seed production was heavy during most years of favorable moisture. It was sufficient every year to produce a new stand of clover, but in some adverse years, such as 1949, almost no plants survived to maturity. In 1952 a heavy seed crop was produced even though stands of rose and bur clover were thin. Germination was so great the next fall that practically every square inch had one to several seedlings.

Rose clover was somewhat less attractive to cattle than most other annual legumes or grasses and was usually last to be moderately utilized. Early in the green forage season native plants were taller and were grazed more than this introduced species. Bur clover was also favored by cattle at this season. Late in the green-forage season during good years, such as 1952, native clover (littlehead and white-tip) were closely grazed. Under the same conditions rose clover was used lightly and bur and sub clovers only light to moderate. In 1952 all species were fully grazed by July 1, but rose clover was last to be so used.

In summer and fall rose clover provided less attractive grazing than earlier. Dry herbage was only moderately grazed, and in some years use of the dry plants was only light. Bur clover, in contrast, was relished by cattle at this season. Dry native clovers were also selected.

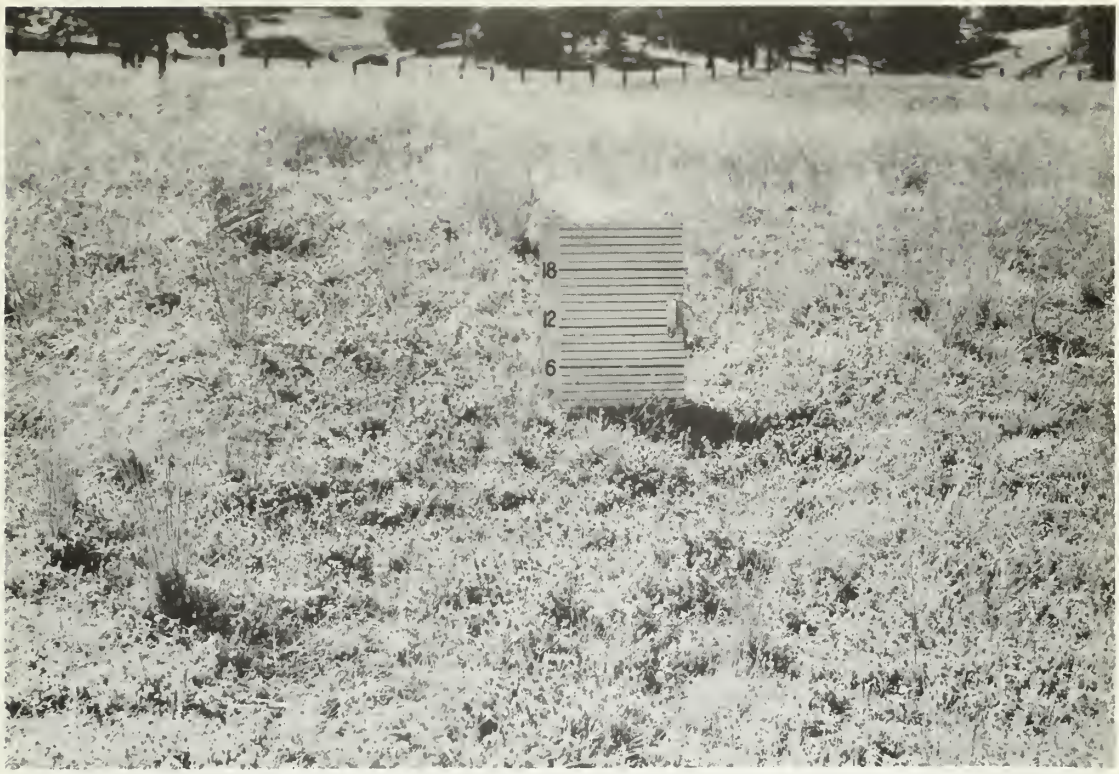

Figure 2.--In unfavorable rainfall years rose clover was typically only 2 to 3 inches high on slope soils.

The relative unpalatability of dry rose clover was the primary reason for failure of an attempt to spread rose clover over the range in livestock manure. Rose clover seedlings compete well and survive when introduced into a stand of residual annuals (9). Dissemination of seed by livestock, therefore, is an appealing idea since it avoids the costly operation of seedbed preparation.

In the fall of 1952 two truckloads of dry rose clover straw containing a considerable amount of seed were spread on two 1/20-acre plots. Each plot was in a different pasture. One pasture had been recently fertilized with 60 pounds of sulfur per acre. The other pasture was fertilized with gypsum about a year after the rose clover was scattered. The cattle were little inclined to eat the rose clover straw; consequently, the seed was not disseminated in the manure as hoped. Molasses was sprayed over the straw to increase palatability, and the cattle then ate some of it. Most of the straw was never eaten.

Table 2.--Plant counts and densities of annual legumes

AVERAGE NUMBER OF PLANTS PER SQUARE FOOT

Date and site	Species: Rose clover	Bur clover	Sub clover	Crimson clover	Hairy vetch	Native Legumes
1953:						
Upland slope	0.8	T	0	0	T[1/]	2/
Intermediate slope	9.4	1.9	0.1	T	T[1/]	2/
Bottomland	0.9	5.1	0.5	0.1	0.1	2/

AVERAGE DENSITY (PERCENT OF GROUND COVERED)

1954:						
Upland slope	6	T	T	0	T	24
Intermediate slope	36	1	1	T	2	7
Bottomland	11	27	3	1	29	8
1955:						
Upland slope	1	T	T	0	T	7
Intermediate slope	7	1	1	T	0	6
Bottomland	2	3	2	T	17	3
1956:						
Upland slope	3	T	T	0	T	7
Intermediate slope	14	T	4	0	0	13
Bottomland	2	2	1	0	24	4
1957:						
Upland slope	3	T	0	0	T	2
Intermediate slope	10	0	1	0	0	7
Bottomland	T	1	0	0	15	2

1/ Not planted--a few occurred at soil type edges.

2/ Not determined.

By mid-December 1952 a mat of seedlings grew under the rose clover straw. Some manure piles around water, feed troughs, and along trails contained variable numbers of seedlings. In May 1953 a sparse stand of rose clover occurred where some straw had been scattered and a few small patches appeared nearby. The plants were healthy, 4 to 5 inches high, and matured seed that year. Much less rose clover germinated in the fall of 1953 even under the straw and on livestock

concentration areas. During succeeding years it became more and more sparse. By 1957 only a very few plants could be found over the same restricted areas.

Other Introduced Legumes

Sub clover was limited to bottomland soil but with fertilization grew well elsewhere during favorable years. It was commonly overtopped by bur clover (fig. 3), hairy vetch, and other plants. It appeared to be about as palatable as bur clover.

Figure 3.--Introduced legumes dominated by bur clover between rows of pampasgrass on fertilized bottomland soil. May 21, 1953.

Crimson clover was never established in abundance. The scattered small patches on the lower slopes and bottomland were too sparse and short lived for proper evaluation of grazing value.

With seeding and fertilization hairy vetch grew well over all the bottomland soil. It persisted in greater abundance than any other legume (table 2). Without fertilization it grew in small patches along an intermittent creek. Hairy vetch was palatable to cattle at all stages of growth and was grazed early, particularly during the dry season.

CONCLUSIONS AND SUMMARY

Considerable effort has been expended in seeding and fertilizing to develop stands of introduced annual legumes in California's annual-plant type. Only moderate success can be claimed under San Joaquin Experimental Range conditions, which are typical of the granite soil belt lying along the east side of the San Joaquin valley.

Almost all success with introduced annual legumes has been on bottomland soils. These soils make up less than 5 percent of the total area. Rose clover, best of the lot for dry sites, required lower-slope or bottomland sites for survival in all except wet years.

All species required periodic fertilization to grow well. Without fertilizer, stands gradually declined. Some disappeared within 3 years from sites where they had previously grown well. All species required good soil-moisture conditions, and production fluctuated greatly with weather conditions.

In the granite belt, a group of native clovers occur generally but fluctuate in production with weather conditions. Fertilization materially increased herbage production in these species. They are equal to or better than introduced legumes in palatability, and sometimes more productive. Native clovers are generally overlooked in range improvement programs, but the simple addition of the proper fertilizer may be all that is needed to create a "legume" range. This is an economically sound practice (3), whereas the seeding and fertilizing needed to produce the introduced species has not yet been evaluated.

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