

## THE EFFECT OF GRAZING INTENSITY ON PLANT COMPOSITION, VIGOR, AND GROWTH OF PINE-BUNCHGRASS RANGES IN CENTRAL COLORADO

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### INTRODUCTION

What happens to individual forage plants when subjected to different degrees of grazing by cattle? In what way does grazing change growth habits and composition of the herbaceous vegetation? Answers to these basic questions will help the range operator to properly evaluate his range-management practices.

Six experimental pastures on native ponderosa pine-bunchgrass range at the Manitou Experimental Forest near Woodland Park, Colorado, furnished an excellent opportunity to study changes in native vegetation in relation to past grazing use. These units had been grazed at 3 intensities for 9 years. In each unit, exclosures, which had not been grazed for 10 years, were available.

### DESCRIPTION OF THE AREA

The pastures are located on alluvial granitic soils in the Trout Creek Valley. These soils are relatively infertile, low in organic matter, and highly erosive. The gently rolling topography has an average easterly aspect with slopes of 10 to 20 per cent. The area is covered with a typical open stand of ponderosa pine (*Pinus ponderosa*)<sup>2</sup> interspersed with grassland parks.

Climatic records at the experimental forest headquarters from 1937 to 1950 show an average annual rainfall of 15.98 inches, with fluctuations ranging from 7.99 inches in 1939, to 25.80 inches in 1947. More than three-fourths of the total precipitation comes during the period of April through September. Normally winters are open with little snowfall. Summer daytime temperatures range from 75° to 85° F. and fall to 35° to 45° F. at night. Winter temperatures average about 40° F. in the daytime and 0° to 5° F. at night.

### METHODS

Beginning in 1941, the 6 pastures were grazed by yearling heifers from June 1 to October 31, at 3 rates of stocking. The heavy rate was estab-

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<sup>2</sup> Nomenclature of plants in this article is based on Standardized Plant Names, second edition, by H. P. Kelsey and W. A. Dayton.

lished at 50 per cent or more utilization of the palatable grass and sedge herbage; the moderate rate at 30 to 40 per cent utilization; and the light rate at 10 to 20 per cent utilization. These rates of grazing were not achieved in the beginning. The light intensity was first achieved in 1942, the moderate rate in 1942 on one pasture and in 1943 on the other, and the heavy rate in 1943 on one pasture and in 1944 on the other. After these dates, the utilization goals were achieved each year.

The current study was conducted during 1949 and 1950, and was based on measurements and observations made at 12 locations in the grassland parks of the pastures. Three sites each year were studied on areas typical of the heavy, moderate, and light rates of grazing and 3 sites were in exclosures that had not been grazed since 1939. New sites were selected each year, the sites being protected from grazing by temporary wire exclosures during the year the observations were made. Although not grazed during the year measurements were made, plants in the heavily grazed pastures are referred to as "heavily grazed"; those in moderately grazed pastures, "moderately grazed"; and those in lightly grazed pastures, "lightly grazed."

A series of 20 sampling plots, each 1 foot wide and 10 feet long, was established within each exclosure in the pastures. Random selection of 10 out of each 20 plots determined the actual plot location. Species segregation on each plot was as follows:

#### Grasses:

Little bluestem (*Andropogon scoparius*)  
Blue grama (*Bouteloua gracilis*)  
Parry oatgrass (*Danthonia parryi*)  
Arizona fescue (*Festuca arizonica*)  
Mountain muhly (*Muhlenbergia montana*)  
Other grasses

#### Grasslike:

Sedges and rushes (*Carex* spp. and *Juncus* spp.)

#### Weeds:

Rose pussytoes (*Antennaria rosea*)  
Nickleaf milkvetch (*Astragalus goniatus*)  
Trailing fleabane (*Erigeron flagellaris*)  
Fringed sagebrush (*Artemisia frigida*)  
Other weeds

On each sample plot, the average height growth; number of seedstalks of grasses; number of seedlings; number of plants and number of tufts per plant for grasses;<sup>3</sup> herbage yield; and litter accumulation were determined for each species. In addition, the air-dry weight of roots in the top cubic foot of soil was determined for three major grasses and soil moisture was determined at monthly intervals on each sampling area.

To determine when and to what extent cattle graze the major forage species, 30 grazed plots in each of the 3 pastures were measured in 1950. Percentage composition of the herbage by volume was estimated at the beginning of the grazing season. Utilization by species was estimated on July 18, August 15, and near the end of the grazing season, September 25.

### RESULTS

Other investigators have shown that heavy grazing of pine bunchgrass ranges tends to remove the more palatable, high-producing grasses from

<sup>3</sup> A tuft was considered as a part of the crown producing green herbage but separated from other producing parts by one-half inch or more of nonproducing crown.

the vegetational complex (Hanson 1924, Costello and Schwan 1946). These are replaced by grasses of lower palatability, usually sod-forming species, and by unpalatable weeds and half-shrubs. Under the heavy rate of stocking, which brought about the most range deterioration, such deterioration had progressed only to the transition from bunchgrasses to sod grass stages (Johnson 1953). The changes brought about by grazing evaluated here are representative of only first stages of retrogression from the climax conditions. Such changes are the first indications that management practices are at fault and that corrective measures are needed.

### Utilization of herbage

The palatable species considered in utilization estimates and their percentage utilization are shown in Figure 1. All species received substantial utilization on the heavy-use areas, but on moderate- and light-use areas, blue grama and fringed sagebrush were only lightly grazed. Mountain muhly and Arizona fescue were grazed most heavily on all except the light-use areas where little

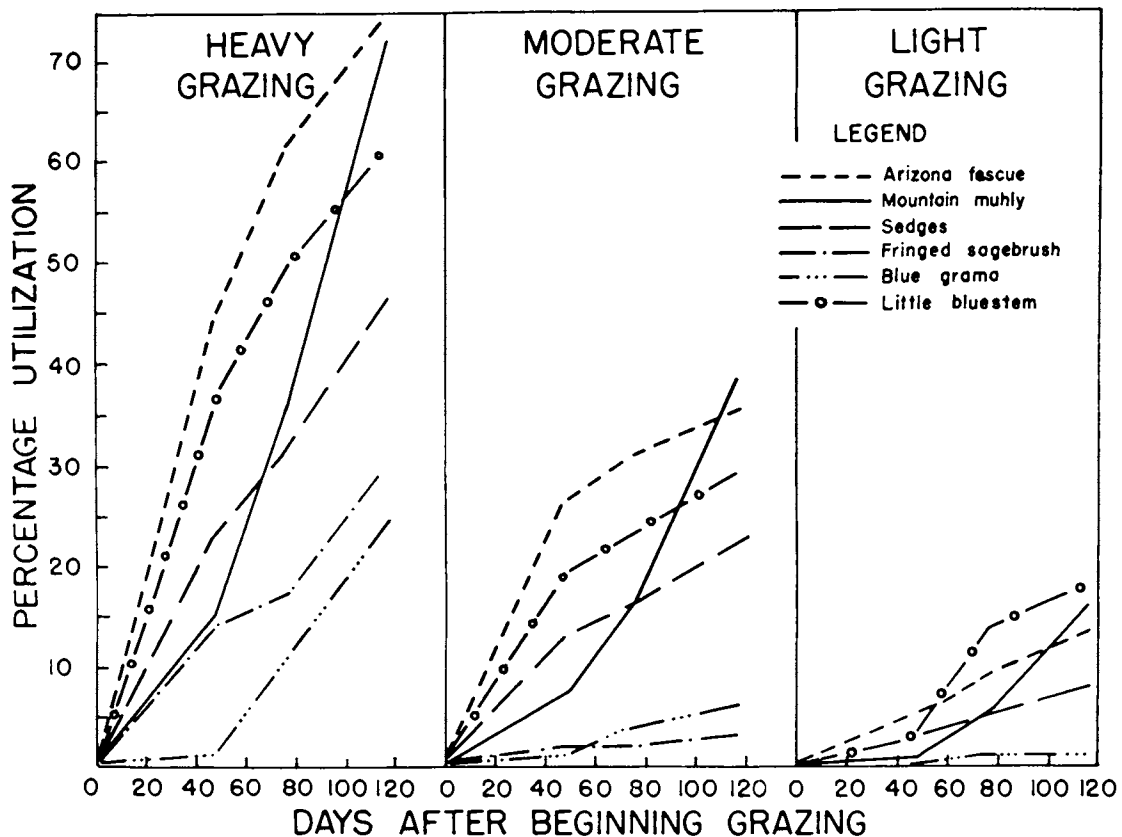


FIG. 1. Seasonal use of major forage species on pine bunchgrass ranges grazed at 3 intensities, Manitou Experimental Forest, 1950.



made up an average of 16 per cent of the total herbage. It was less abundant on moderately grazed areas and became a minor component on lightly grazed and ungrazed areas. Although it occurred frequently, it did not become prominent except under heavy grazing use. Both Crafts (1937) and Nichol (1937) report similar trends for blue grama on overgrazed ranges in Arizona.

Little bluestem and Parry oatgrass were rarely prominent in the composition except on localized areas. Both species had a tendency to grow in colonies and were not uniformly scattered over the range. Consequently, there was no consistent frequency of their occurrence on the sample plots.

Other grasses, principally the wheatgrasses (*Agropyron* spp.), prairie junegrass (*Koeleria cristata*), and bottlebrush squirreltail (*Sitanion hystrix*) were not present in appreciable amounts except on light- and non-use areas. The wheatgrasses (principally *Agropyron smithii* and *A. subsecundum*) were more frequently associated with lighter rates of grazing, whereas tumblegrass (*Schedonnardus paniculatus*) and pullup muhly (*Muhlenbergia filiformis*) were more typical of the heavily grazed areas.

The weed cover on heavily grazed ranges formed more than half of the total composition, but was only about one-fourth of the total cover elsewhere. Rose pussytoes and trailing fleabane were prominent on heavily grazed areas and, in general, became consistently less prominent as grazing decreased. Fringed sagebrush was almost as abundant on none-use areas as on those heavily grazed, but was much reduced on both moderately and lightly grazed areas. Nickleaf milkvetch, a palatable legume, increased in frequency as the degree

of grazing use was reduced, but was never an abundant part of the composition.

On pine-bunchgrass ranges in central Colorado, Arizona fescue and mountain muhly are the most important forage species in the herbaceous cover. Management, therefore, should be based on keeping these grasses in a healthy, productive condition. Little bluestem and Parry oatgrass may sometimes be abundant enough locally to provide substantial amounts of forage. An increasing abundance of blue grama (Fig. 2), rose pussytoes, trailing fleabane, and fringed sagebrush indicates that depletion is resulting from too heavy grazing use and that corrective measures are needed. On many ranges in the ponderosa pine zone, the native bunchgrasses have been completely eliminated and blue grama is the dominant grass species.

#### Occurrence

The number of plants per plot of most of the species was related to grazing intensity (Table II). Species reactions differ but the difference in response between the palatable and unpalatable species provides information for evaluating range-management practices.

Plants of blue grama was most abundant on heavily grazed plots and least abundant on lightly grazed plots. In contrast, plants of Arizona fescue, a palatable species, were more numerous on areas where utilization was moderate or less. Mountain muhly plants were most numerous on heavily grazed areas, but they were smaller and weaker plants. Actually, many of the units that appeared to be separate plants may have been the result of disintegration of originally larger clumps.

Plants of other species of grass were consider-

TABLE II. Average number of plants per plot in relation to grazing intensity, Manitou Experimental Forest—1949, 1950

| Species                 | PAST GRAZING TREATMENT |       |       |          |      |      |          |      |      |          |      |      |
|-------------------------|------------------------|-------|-------|----------|------|------|----------|------|------|----------|------|------|
|                         | Heavy                  |       |       | Moderate |      |      | Light    |      |      | None     |      |      |
|                         | 1949                   | 1950  | Ave.  | 1949     | 1950 | Ave. | 1949     | 1950 | Ave. | 1949     | 1950 | Ave. |
| <i>Grass</i>            | (Number)               |       |       | (Number) |      |      | (Number) |      |      | (Number) |      |      |
| Little bluestem.....    | 9.3                    | 1.7   | 5.5   | —        | —    | —    | 3.6      | 13.6 | 8.3  | 0.5      | T*   | 0.2  |
| Blue grama.....         | 27.7                   | 32.5  | 30.1  | 26.3     | 21.7 | 24.0 | 4.6      | 7.2  | 5.9  | 7.8      | 7.9  | 7.8  |
| Parry oatgrass.....     | .8                     | 0     | .4    | —        | —    | —    | .9       | 9.6  | 5.2  | .2       | .9   | .5   |
| Arizona fescue.....     | 1.2                    | 2.9   | 2.0   | 8.7      | 8.9  | 8.8  | 5.0      | 3.1  | 4.0  | 12.4     | 13.0 | 12.7 |
| Mountain muhly.....     | 28.6                   | 49.0  | 38.8  | 28.1     | 45.9 | 37.0 | 23.9     | 34.2 | 29.0 | 20.1     | 31.7 | 25.9 |
| <i>Sedge</i> .....      | 110.9                  | 102.6 | 106.7 | 47.4     | 70.4 | 58.9 | 59.0     | 29.1 | 44.0 | 38.6     | 69.0 | 53.8 |
| <i>Weeds</i>            |                        |       |       |          |      |      |          |      |      |          |      |      |
| Rose pussytoes.....     | 55.9                   | 64.7  | 60.3  | 44.6     | 19.6 | 32.1 | 25.2     | 17.6 | 21.4 | 12.8     | 7.1  | 10.0 |
| Nickleaf milkvetch..... | 1.7                    | 4.7   | 3.2   | 4.4      | 4.8  | 4.6  | 1.6      | 2.8  | 2.2  | 4.9      | 7.3  | 6.1  |
| Trailing fleabane.....  | 30.5                   | 10.9  | 20.7  | 4.6      | 17.4 | 11.0 | 7.1      | 22.1 | 14.6 | 4.4      | 9.7  | 7.0  |
| Fringed sagebrush.....  | 18.5                   | 20.5  | 19.5  | 11.5     | 12.7 | 12.1 | 6.1      | 4.3  | 5.2  | 15.4     | 14.2 | 14.8 |

\*Less than 0.05 plant per plot



FIG. 2. Invasion of blue grama (upper) and deterioration of mountain muhly (lower) on heavily grazed pine-bunchgrass ranges.



FIG. 3. Typical weak growth of mountain muhly on heavily grazed ranges. Small tufts of grass are confined to the perimeter of the crown.

ably more numerous on light- and non-use areas than on those grazed moderately or heavily. The number of sedge plants was not consistent between grazing intensities, but was greater on the heavy-use area.

The number of plants of rose pussytoes was greatest on heavy-use areas and least on ungrazed areas. Nickleleaf milkvetch fluctuated too much to indicate any trend. Trailing fleabane was much more numerous on heavily grazed plots than on plots with other types of use. The number of plants of fringed sagebrush was less under lighter grazing, but was nearly as abundant on ungrazed areas as on those heavily grazed.

#### *Growth habit*

The growth form of the plants was also related to grazing intensity. The bunchgrasses had a greater number of grass tufts per plant on heavily grazed areas than on areas more conservatively grazed. The tufts, however, were small, weak growths, confined to the perimeter of the crown (Fig. 3). In many cases it was difficult to determine whether a group of plants had originally been a larger plant that had broken up into smaller units as a result of being weakened by too heavy use. On lightly grazed ranges, grass tufts were larger and scattered uniformly over the plant crown, and the crowns formed distinct units. Two types of dead centers of grass plants were conspicuous. Plants with dead centers resulting from old age still retained a comparatively wide band of vigorous growth around the edge of the crown, and stubble from previous years was abundant. Dead centers resulting from too heavy grazing were different. There was a noticeable lack of old growth on the plant, and the live parts of the crown produced a weak spindly type of growth.

Among the weeds, two species were conspicuous

in the different growth forms associated with different intensities of grazing. Normal growth of nickleleaf milkvetch is a spreading, semierect type of foliage, but on heavily grazed areas the leaves of the plants were prostrate. Fringed sagebrush, in competition with the native bunchgrasses on ungrazed areas, was an erect shrubby type of growth and produced numerous seedstalks. On grazed areas, particularly those moderately or heavily grazed, seedstalks were few but a dense basal growth, almost of mat form, developed.

Healthy condition in bunchgrass ranges is reflected in fewer plants of most species, but a more prolific and vigorous type of erect growth (Fig. 4). Ungrazed plants have a tendency to develop into large robust units. Extensive root systems are developed and invasion by other plants into bare soil areas is reduced to a minimum. Consequently, the lighter the degree of grazing use the greater is the tendency toward fewer but larger plants. Most species that occurred with sufficient frequency to establish clear-cut trends had a maximum number of individual plants on heavily grazed areas. Arizona fescue was an exception to this rule.

#### *Seedlings*

The number of grass seedlings on heavy-, moderate-, and light-use areas were about the same; 9.3, 9.6, and 8.0, respectively. On ungrazed areas, 15.9 seedlings per plot occurred. This indicates that the microclimatic conditions necessary for germination and growth of grass seedlings are more favorable under non-use than on grazed ranges.

Weed seedlings indicated a closer relationship to grazing treatment than the grasses. The number of seedlings of trailing fleabane and fringed sagebrush was greater on heavy-use areas than for

the other areas. Seedlings of rose pussytoes were abundant on both moderate- and heavy-use areas. All of these species are commonly termed indicators of overgrazing. Nickleaf milkvetch seedlings were least abundant on the heavy-use areas and increased as grazing use became lighter. The number of weed seedlings per plot for the different past grazing intensities was as follows:

| Species               | Heavy | Moderate | Light | None |
|-----------------------|-------|----------|-------|------|
| Rose pussytoes        | 3.8   | 6.1      | 1.1   | 0.2  |
| Nickleaf milkvetch    | 1.1   | 2.1      | 3.7   | 11.1 |
| Trailing<br>flecabane | 36.3  | 1.9      | 2.0   | 2.1  |
| Fringed sagebrush     | 6.0   | 4.2      | 1.7   | 3.6  |

### Seedstalks

Mountain muhly and little bluestem were the only two species that indicated a correlation between number of seedstalks per plant and the intensity of grazing use. Ungrazed plants of these species produced 10 to 12 times more seedstalks than plants heavily grazed. There was a noticeable lack of trend in all other species. Usually, Arizona fescue produces an abundance of seedstalks, but in 1949 they were very rare, even in the ungrazed exclosures. This indicates that other factors, such as weather, may be a controlling influence in seedstalk production.



FIG. 4. Healthy plants of mountain muhly have a prolific and vigorous growth over most of the plant crown.

### Height growth

One of the most consistent trends shown was the relationship between the height growth of the leaves of palatable plants and the intensity of past grazing use. In most cases, both the grasses and the sedges grew almost twice as tall under complete protection as they did on heavily grazed areas (Table III). These results indicate the reduced vigor of the plants is a result of heavy grazing pressure.

TABLE III. Average leaf height growth of major species, Manitou Experimental Forest—1949, 1950

| Species            | GRAZING TREATMENT |      |          |      |          |      |          |      |
|--------------------|-------------------|------|----------|------|----------|------|----------|------|
|                    | Heavy             |      | Moderate |      | Light    |      | None     |      |
|                    | 1949              | 1950 | 1949     | 1950 | 1949     | 1950 | 1949     | 1950 |
|                    | (inches)          |      | (inches) |      | (inches) |      | (inches) |      |
| <i>Grass</i>       |                   |      |          |      |          |      |          |      |
| Little bluestem    | 3.0               | 1.8  | —        | —    | 3.8      | 2.9  | 2.4      | 3.0  |
| Blue grama         | 1.7               | 1.1  | 1.8      | 1.3  | 2.3      | 1.5  | 3.0      | 2.0  |
| Parry oatgrass     | 3.4               | —    | —        | —    | 4.9      | 4.2  | 6.5      | 9.8  |
| Arizona fescue     | 6.0               | 3.2  | 9.6      | 8.2  | 10.0     | 9.4  | 10.0     | 10.1 |
| Mountain muhly     | 3.3               | 2.1  | 4.0      | 3.2  | 4.7      | 3.6  | 6.3      | 4.4  |
| <i>Sedge</i>       | 2.9               | 2.4  | 4.1      | 3.2  | 4.2      | 2.8  | 5.8      | 4.2  |
| <i>Weeds</i>       |                   |      |          |      |          |      |          |      |
| Rose pussytoes     | .5                | .5   | .5       | .5   | .5       | .5   | .7       | .5   |
| Nickleaf milkvetch | 4.4               | 1.5  | 4.2      | 2.1  | 5.7      | 1.7  | 5.7      | 3.1  |
| Trailing flecabane | 1.0               | .8   | 1.0      | .7   | 1.0      | .8   | 1.1      | .5   |
| Fringed sagebrush  | 2.5               | 1.9  | 2.9      | 2.3  | 2.5      | 2.4  | 4.1      | 3.5  |

The average leaf height of blue grama, Arizona fescue, and mountain muhly consistently increased from heavy use through moderate-, light-, and non-use. Even the sedges showed an increased height growth under lighter rates of grazing. This is one of the few factors studied in which the sedges showed a definite trend with respect to the intensity of grazing.

For the two unpalatable weeds, there appeared to be little or no relation between height growth and grazing use. Rose pussytoes and trailing flecabane made about the same growth on all areas. Nickleaf milkvetch showed differences similar to the palatable grasses. Height growth was least under heavy grazing and greatest on protected areas. Fringed sagebrush varied considerably, but height growth tended to be greater on the lighter use areas.

In using height growth as a measure of plant vigor, seasonal differences in growth cannot be ignored. In most cases, the height growth in 1950 was significantly shorter than in 1949 because of drought. Only 11.61 inches of precipitation fell during 1950, most of it in small amounts that had little effect on soil moisture.

### Herbage yield

The total herbage clipped during 1949 from areas heavily grazed was 939 pounds per acre. In contrast, moderate-, light-, and non-use areas produced 1,175, 1,115, and 1,980 pounds per acre, respectively. An even greater contrast appeared in the yield of grass and sedge. Only 477 pounds per acre was produced on heavily grazed areas while 785, 841, and 1,493 pounds per acre were produced under moderate-, light-, and non-use, respectively (Table IV).

Yields in 1950 were much lower on all areas be-

TABLE IV. Yields of air-dry herbage by degrees of grazing use, Manitou Experimental Forest—1949, 1950

| Species               | GRAZING TREATMENT |      |                   |      |                   |      |                   |      |
|-----------------------|-------------------|------|-------------------|------|-------------------|------|-------------------|------|
|                       | Heavy             |      | Moderate          |      | Light             |      | None              |      |
|                       | 1949              | 1950 | 1949              | 1950 | 1949              | 1950 | 1949              | 1950 |
|                       | (Pounds per acre) |      | (Pounds per acre) |      | (Pounds per acre) |      | (Pounds per acre) |      |
| <i>Grass</i>          |                   |      |                   |      |                   |      |                   |      |
| Little bluestem       | 38                | 3    | —                 | —    | 37                | 44   | 9                 | —    |
| Blue grama            | 140               | 133  | 74                | 65   | 12                | 20   | 21                | 15   |
| Parry oatgrass        | 2                 | —    | —                 | —    | 8                 | 46   | 2                 | 15   |
| Arizona fescue        | 22                | 9    | 343               | 247  | 222               | 74   | 254               | 165  |
| Mountain muhly        | 204               | 143  | 299               | 233  | 339               | 199  | 979               | 392  |
| Other grasses         | 20                | 17   | 26                | 13   | 172               | 84   | 149               | 61   |
| Total                 | 426               | 305  | 742               | 558  | 790               | 467  | 1414              | 648  |
| <i>Sedge</i>          | 51                | 37   | 43                | 53   | 51                | 12   | 79                | 73   |
| Total grass and sedge | 477               | 342  | 785               | 611  | 841               | 479  | 1493              | 721  |
| <i>Weeds</i>          |                   |      |                   |      |                   |      |                   |      |
| Rose pussytoes        | 170               | 204  | 88                | 44   | 76                | 68   | 89                | 32   |
| Nickleaf milkvetch    | 21                | 7    | 14                | 11   | 8                 | 5    | 37                | 26   |
| Trailing fleabane     | 36                | 5    | 3                 | 5    | 3                 | 11   | 2                 | 9    |
| Other weeds           | 132               | 78   | 220               | 85   | 174               | 66   | 162               | 39   |
| Total                 | 359               | 294  | 325               | 145  | 261               | 150  | 290               | 106  |
| Fringed sagebrush     | 103               | 133  | 65                | 72   | 13                | 26   | 197               | 142  |
| Total                 | 939               | 769  | 1175              | 828  | 1115              | 655  | 1980              | 969  |

cause of drought, but the differences related to grazing intensity followed the same general pattern. Grass and sedge herbage on heavily grazed areas in 1950 were reduced 28 per cent. On moderate-use areas the reduction amounted to 22 per cent; on light-use areas, 43 per cent; and on ungrazed areas, 51 per cent.

It is significant that in this comparison the moderately grazed areas suffered the least from drought and the non-use areas the most. Plants weakened by too heavy grazing would explain the greater damage on areas heavily grazed, but more study is needed to evaluate the proportionally greater decreases under light grazing and no use. Drought effects were reflected in reduction of top growth rather than in death of plants.

Herbage yield of individual species reflects the effect of different intensities of grazing. As an example, the yield of blue grama was highest under heavy grazing, but was very low under light- and non-use. This grass is relatively unpalatable on pine-bunchgrass ranges when bunchgrasses are available.

Arizona fescue and mountain muhly, the main forage grasses, produced an average of only 15 and 173 pounds per acre, respectively, under heavy grazing. Under moderate grazing, Arizona fescue produced an average of 295 pounds and mountain muhly, 266 pounds per acre. The yield of the latter was even greater under light grazing and

under non-use, but Arizona fescue yields were less. Under light and moderate rates of grazing there is not enough use of fescue to weaken the plants and the variation shown is probably natural fluctuation in composition. Under heavy grazing, the cattle make heavier use of fescue, and since it is more susceptible to injury from heavy grazing, the yields are greatly reduced.

Little bluestem and Parry oatgrass were not plentiful enough to furnish reliable data on yields. The yield of other grasses, principally prairie junegrass, bottlebrush squirreltail, and several of the wheatgrasses, was highest under the lighter rates of grazing use. The yield of sedges did not appear to be related to grazing intensity even though the plants are palatable.

Among the weeds, rose pussytoes, trailing fleabane, and fringed sagebrush all produced higher herbage yields on areas heavily grazed than on those either lightly or moderately grazed. The production of fringed sagebrush, however, was heaviest on the ungrazed areas. Here a more favorable microclimate resulted in greater height growth and more seedstalks. Nickleaf milkvetch is a palatable plant, but in this study it produced greater yields under heavy and moderate grazing than under light use. Yields were maximum on non-use areas.

#### Root growth

Plants of little bluestem, Arizona fescue, and mountain muhly were dug from areas representative of each of the four grazing intensities studied. The air-dry weights of the roots in the surface cubic foot of soil were compared with air-dry weight of the tops to determine the ratio of the top growth to root growth (Table V).

TABLE V. Ratio of air-dry weights of top growth of major forage grasses to their root growth in the surface cubic foot of soil, Manitou Experimental Forest—1949

| Species         | GRAZING INTENSITY |          |       |      |
|-----------------|-------------------|----------|-------|------|
|                 | Heavy             | Moderate | Light | None |
| Little bluestem | 2.37              | 3.86     | 3.32  | 3.69 |
| Arizona fescue  | 2.53              | 3.20     | 3.10  | 3.22 |
| Mountain muhly  | 2.71              | 3.63     | 3.35  | 4.20 |
| Average         | 2.54              | 3.56     | 3.26  | 3.71 |

All three species indicated a similar response to grazing. On heavily grazed areas the plants produced about 2½ units of foliage to 1 unit of roots. On the areas grazed less heavily, the ratio for all species was about 3½ to 1 (Fig. 5). The variation among moderate-, light-, and non-use areas appeared to be normal differences but the ratio on

the heavily grazed areas is a definite effect of grazing. This would indicate that moderate or lighter use of the plants by livestock does not weaken the root growth in the first foot of soil sufficiently to reduce their vigor.

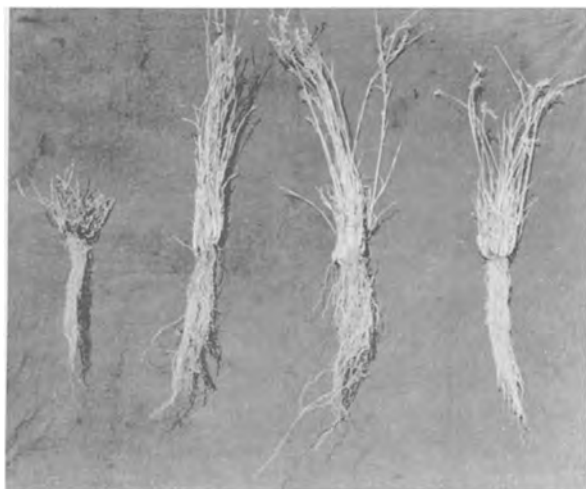


FIG. 5. Plants of little bluestem from (left to right) heavy-, moderate-, light-, and non-use areas. Root and top growth developments are typical.

#### *Litter*

The amount of herbaceous litter on the ground is important in determining the amount of precipitation that enters the soil (Johnson 1940). On heavily grazed areas, there was only 807 pounds of litter per acre compared with 1,174 pounds on the moderately grazed range; 1,115 pounds on the lightly grazed range; and 1,980 pounds on non-use areas. On the non-use areas, there was a definite humus layer beneath the litter. This was entirely absent on the heavily grazed areas. A humus layer was present on moderately and lightly grazed areas, but was not as pronounced as in the ungrazed enclosures.

#### *Soil moisture*

Soil samples were obtained from each of the exclosures at monthly intervals from June 15 to September 15 to determine what effect the different degrees of grazing had on soil moisture. The amount of soil moisture for June, July, and August was about the same on the heavy-, moderate-, and light-use areas at both the 0- to 6- and 6- to 12-inch depth (Table VI). On the ungrazed areas, however, moisture in the surface layer was about 43 per cent greater, and in the 6- to 12-inch layer about 48 per cent greater than on the grazed areas. Moisture content during June and July remained at about the same level, but dropped about 50 per cent during August and September.

TABLE VI. Soil moisture in relation to grazing intensity Manitou Experimental Forest—1949

| Date            | Soil<br>depth | GRAZING INTENSITY |               |       |       |  |
|-----------------|---------------|-------------------|---------------|-------|-------|--|
|                 |               | Heavy             | Moder-<br>ate | Light | None  |  |
|                 | (Inches)      |                   | (Per cent)    |       |       |  |
| 6/20/49 . . . . | 0-6           | 14.02             | 12.96         | 13.18 | 19.10 |  |
|                 | 6-12          | 10.25             | 10.21         | 9.60  | 14.83 |  |
| 7/15/49 . . . . | 0-6           | 14.56             | 14.65         | 13.00 | 20.20 |  |
|                 | 6-12          | 11.88             | 12.30         | 10.04 | 14.74 |  |
| 8/15/49 . . . . | 0-6           | 7.22              | 8.85          | 7.49  | 9.60  |  |
|                 | 6-12          | 5.20              | 3.79          | 4.62  | 6.82  |  |
| 9/15/49 . . . . | 0-6           | 6.41              | 7.59          | 9.38  | 12.61 |  |
|                 | 6-12          | 3.28              | 3.33          | 4.55  | 6.19  |  |

Rainfall during the week prior to the September measurements produced some interesting changes in the soil moisture conditions. On heavily and moderately grazed areas, soil moisture at both depths was less than in August but on lightly grazed areas surface moisture increased 2 per cent and on ungrazed areas it increased 3 per cent. The moisture in the 6- to 12-inch layer decreased similarly to that on heavy- and moderate-use areas. The increase in the surface soil moisture on light- and non-use areas is probably related to factors affecting infiltration such as litter, compaction through trampling, or others that are not yet thoroughly understood.

#### SUMMARY

A study was made to determine the effect of grazing intensity on plant composition, vigor, and growth of pine-bunchgrass ranges. Grassland parks in 6 pastures that had been grazed at 3 intensities by cattle, and ungrazed exclosures in each range unit furnished the background for the study. The dates when the desired intensities of grazing in the units were first achieved varied by units from 1942 to 1944. In 1949 and 1950, temporary exclosures in the grassland areas of the range units provided the seasonal response of the plants following the prescribed intensity of grazing. From these temporary exclosures and exclosures ungrazed since 1939, data were obtained on species composition and frequency, utilization, number of plants and growth habits, number of seedlings, seedstalk production, height growth, herbage yield, root development, and litter accumulation. The results of this study indicate the following conditions and responses may be expected on pine-bunchgrass ranges.

Grasses formed the bulk of the palatable forage used by cattle. Arizona fescue and mountain muhly were the most important and most abundant forage species.

Progressively increasing amounts of blue grama,

rose pussytoes, trailing fleabane, and fringed sagebrush occurred on lightly, moderately, and heavily grazed range.

The ungrazed ranges were characterized by comparatively small numbers of large plants per given unit of area, although Arizona fescue occurred in markedly greater numbers on the ungrazed areas than under any other treatment. The grass tufts were large and uniformly distributed over the plant crowns. Heavily grazed areas were characterized by a larger number of smaller plants of some species with smaller grass tufts usually confined to the outside edge of the crown. Arizona fescue plants were both fewer in number and smaller in size on the heavily grazed area than under the other grazing intensities.

Grass seedlings were most abundant on ungrazed areas. There was no apparent difference in the density of grass seedlings on ranges grazed at heavy, moderate, or light intensities.

Weed seedlings were closely correlated with intensity of grazing. Rose pussytoes, trailing fleabane, and fringed sagebrush seedlings were most abundant on heavily grazed areas. Nickleaf milk-vetch seedlings were most abundant on ungrazed areas.

The effect of grazing on production of seed-stalks was obscured by adverse weather effects. Little bluestem and mountain muhly were the only species to show a correlation between seedstalk production and grazing intensity.

Height of leaf growth was the most consistent plant response to the different grazing intensities. Leaf growth was shortest on areas that had re-

ceived heavy grazing and longer under the lighter grazing intensities. Variations in weather also have an effect on height of leaf growth, but differences between the different grazing intensities were consistent.

Root development in relation to top growth was impaired by heavy grazing use. No impairment of root growth was observed under moderate and light grazing.

Herbage yield of perennial grasses and sedges was greatest on ungrazed range and progressively less on the lightly, moderately, and heavily grazed ranges. Blue grama produced more on the heavily grazed range and least on the lightly and ungrazed ranges, whereas mountain muhly and Arizona fescue were least productive on the heavily grazed areas. Low valued weeds and fringed sagebrush tended to be most productive on heavily grazed ranges.

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## CHANGES IN A CALIFORNIA ANNUAL PLANT COMMUNITY INDUCED BY MANIPULATION OF NATURAL MULCH<sup>1</sup>

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The dead plant materials above the soil surface in natural grasslands are usually referred to as litter, mulch, or plant residue. This material varies in position from lying directly on the soil to standing upright in a tangled mass. It may also be in all stages of decomposition and in many degrees of compactness. The kinds of plants which contribute to the mulch layer are many and therefore the nature of the material itself is varied.

For purposes of study and accurate description, the total mulch has been divided into layers. The upper portion of unconsolidated and undecomposed material is litter to the forester and the A<sub>00</sub>

layer in soil science. It has also been called fresh mulch and forage residue. The latter term seems the most descriptive for grasslands since much of that material may be eaten by livestock, however poor it is for feed. For example, the diet of animals grazing on the California annual type during the winter contains a considerable proportion of this material along with young and very succulent green herbage.

The partially decomposed material on the soil surface is known as raw humus, the A<sub>0</sub> layer or, preferably for grasslands, humic mulch. Little is ever eaten by livestock. It becomes humus when decomposition proceeds to a point so that the origin of the material is no longer recognizable and

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