# Severe Mechanical and Chemical Range Renovation in Northeastern Wyoming

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**Highlight**: *Range renovation using a moldboard plow, disc plow, rotovator, blade, and strip spraying with atrazine was evaluated on a clayey and a sandy range site 35 miles south of Gillette, Wyoming. Herbage yields and vegetative composition were influenced by the individual renovation treatment, range site, and distribution and amount of April, May, and June precipitation. The amount of total perennial grass was significantly increased on the plots treated with the rotovator and strip spraying with atrazine on the clayey site, and on plots treated with atrazine on the sandy site. The 5-year average yield of blue grama from the atrazine treatments averaged 872 and 939 lb/acre on the clayey and sandy range sites, respectively, as compared with 237 and 229 lb/acre, respectively, on the check. The blue grama on plots sprayed with atrazine produced a profusion of seed heads and remained green later in the season than on any of the other treatments. The disc plow and the rotovator appear to have a greater potential than the moldboard plow or blade for range renovation. Annual grasses may become a problem with any range renovation, and should be controlled.*

Various mechanical treatments have been used on rangelands to increase herbage production, improve species composition, and reduce surface runoff and erosion. Pitting, contour furrowing, and ripping have been the most widely used methods for range renovation on the Great Plains rangelands. Abandoned farm lands usually are more productive because more of the desirable species are present than on the undisturbed contiguous native rangeland in poor or fair condition. This indicates that a more severe tillage treatment than pitting or furrowing may be needed to improve some range sites. Thatcher (1966) studied a clayey range site in northeastern Wyoming that was disc plowed and abandoned and stated that mechanical treatments applied in the past may not have been as severe as they should have been. Powell and Box (1967) found that soil disturbance in south Texas retarded secondary plant succession and that brush control with a minimum of soil disturbance was the most reliable method of improving the successional stage and increasing herbage production.

Branson et al. (1966) stated that for a mechanical treatment to have a lasting effect it must modify the soil surface and in such a manner that precipitation is retained and stored in the soil. Wight and Siddoway (1972) concluded that the beneficial effects of five surface modification treatments on rangelands in Montana were due to increased soil water, improved species composition, and increased nutrient supply.

Weathering and decomposition of organic matter release plant nutrients when the soil is tilled or cultivated. The magnitude of the tillage determines the longevity and amount of the fertility benefit. McCalla (1967) stated that tillage, with subsequent aeration and mixing of the residues with the soil, stimulated the ammonifying and nitrifying microorganisms.

This study was made to evaluate the effects of four severe tillage treatments and a herbicide applied in strips on herbage production and species composition of a clayey and a sandy range site in northeastern Wyoming.

## Methods

The study area was about 35 miles south of Gillette, Wyo., at an elevation of about 5,000 ft, in a 10- to 12-inch precipitation zone. Rangeland for the experimental area was furnished by the Durham Ranches, Inc. The clayey range site was on a north-facing 5% slope and was rated in low fair range condition. Soils were Renohill and Ulm clay loam, members of a fine montmorillonitic mesic family of Ustollic Haplargids. The two soils do not differ agronomically, although the Renohill soil is shallower than the Ulm soil. The sandy range site was on a nearly level area that was rated in low good range condition. Soil was Maysdorf fine sandy loam, a member of a fine loamy, mixed mesic family of Ustollic Haplargids. The two range sites were about 5 miles apart.

Blue grama (*Bouteloua gracilis*) was the dominant species on both range sites. Other vegetation present in varying amounts on both sites included western wheatgrass (*Agropyron smithii*), needleandthread (*Stipa comata*), Sandberg bluegrass (*Poa secunda*), dryland sedges (*Carex* spp.), big sagebrush (*Artemisia tridentata*), plains prickly pea (*Opuntia polyacantha*), annual grasses and annual and perennial forbs.

In October 1967, plots, 25 X 100 ft, were established on both range sites. The experimental design was a randomized complete block with six treatments and three replications. Treatments used included a rotovator, disc plow (D-plow), moldboard plow (M-plow), and a road patrol (blade) and a check.

Fifteen pounds/acre of active atrazine were applied in strips on the atrazine plots with a hand-operated sprayer on April 30, 1968. The sprayed strips averaged 14 inches wide leaving 8 inches of nonsprayed area between the sprayed strips. Experimental areas were fenced to protect them from grazing the first years. Fences were removed in early spring, 1970. The light grazing on the

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The author is indebted to the Durham Ranches, Inc., for providing the land for the research area, and gratefully acknowledges the assistance of Albert P. Thatcher, Soil Conservation Service, formerly of Casper, Wyo., now located in Phoenix, Arizona; Charles McAfee and Paul Lupcho, Soil Conservation Service, Casper and Sheridan, Wyo.; Kerry Zappla formerly with the Soil Conservation Service; Leland Landers, substation superintendent, University of Wyoming; and Art Bosco, foreman of the Durham Ranches, Inc., Gillette, Wyo.

The work is a contribution from the Western Region, U.S. Dep. Agr., Agricultural Research Service, JA 676.

Manuscript received May 2, 1974.

Table 1. Precipitation (inches), April through September at the clayey and sandy range sites at the Durham Ranches Inc., Gillette, Wyo., 1968-1972.

| Months | Clayey site | | | | | | Sandy site | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1968 | 1969 | 1970 | 1971 | 1972 | Total | 1968 | 1969 | 1970 | 1971 | 1972 | Total |
| April | 0.78 | 0.74 | 0.98 | 2.61 | 1.70 | 6.81 | 0.65 | 0.87 | 0.90 | 2.21 | 1.39 | 6.02 |
| May | 1.98 | 0.69 | 4.53 | 1.93 | 2.05 | 11.18 | 1.98 | 0.53 | 4.27 | 1.80 | 1.46 | 10.04 |
| June | 2.97 | 1.90 | 1.87 | 2.97 | 1.77 | 11.48 | 2.91 | 1.50 | 2.84 | 3.78 | 1.75 | 12.75 |
| July | 0.83 | 2.29 | 1.13 | 0.88 | 0.94 | 6.07 | 0.75 | 2.86 | 1.53 | 0.90 | 1.24 | 7.28 |
| August | 1.33 | 0.18 | 0.01 | 0.19 | 3.25 | 4.96 | 1.95 | 0.07 | 0.00 | 0.00 | 3.62 | 5.64 |
| September | 1.00 | 0.11 | 0.64 | 1.10 | 1.14 | 3.99 | 0.77 | 0.19 | 1.18 | 0.85 | 1.09 | 4.08 |
| Means | 8.89 | 5.91 | 9.16 | 9.68 | 10.85 | 44.49 | 9.01 | 6.02 | 10.72 | 9.54 | 10.55 | 45.87 |

experimental areas after the fences were removed had little or no effect on the vegetative composition. In June, 1970, the sandy site, including the experimental area, was aerial sprayed with 2,4-D to control big sagebrush.

In the spring of each year (1968 through 1972) three 4-ft$^2$ subplots (14-5/16 by 40-1/4 inches) were randomly selected in each main plot to determine herbage yields. Previous year's vegetation on these subplots was removed. Herbage within subplots was harvested each September and separated by major species. Annual grasses and forbs and Sandberg bluegrass matured early; thus, part of their production was lost before harvest. Subplots were caged to protect them from grazing after fences were removed.

Air-dry herbage yields were determined for the major species, total grass, dryland sedges, and for total herbage (including minor species not listed separately). Vegetative composition was determined by weight. Herbage yields were analyzed by analysis of variance. Regression analysis between percentage herbage yields of blue grama and western wheatgrass were determined. Duncan's multiple range test for significance was applied at the 5% probability level.

During the first week of June 1973, ten 1- by 1-ft plots on each main plot were selected at random on both range sites and western wheatgrass culms were counted.

## Results and Discussion

Renovation treatments reduced major species and total herbage production the first year. Thereafter, yields varied with years and treatments. Distribution and amount of April, May, and June precipitation influenced the herbage yields in this area. Over 60% of the seasonal precipitation was received during April, May, and June, (Table 1), when it was used most efficiently by the cool season species. Amount of precipitation varied widely among years and months, but total seasonal precipitation for the two range sites was similar.

Herbage yields and individual species differed significantly among years as results of renovation treatments and amount and distribution of precipitation. Annual grasses and forbs increased more on plots mechanically treated than on the check or herbicide-treated plots. Amounts of annual grasses and forbs varied with the range site. Annual grasses common to both range sites were cheatgrass brome (*Bromus tectorum*), Japanese brome (*Bromus japonicus*), and sixweeks-fescue (*Vulpia octoflora*).

For convenience of discussion the results obtained from the treatments will be discussed separately. The clayey and sandy range sites hereafter will be referred to as clayey and sandy sites.

### Check Treatment

Although the vegetation on the clayey and sandy check sites was in low fair and low good condition,

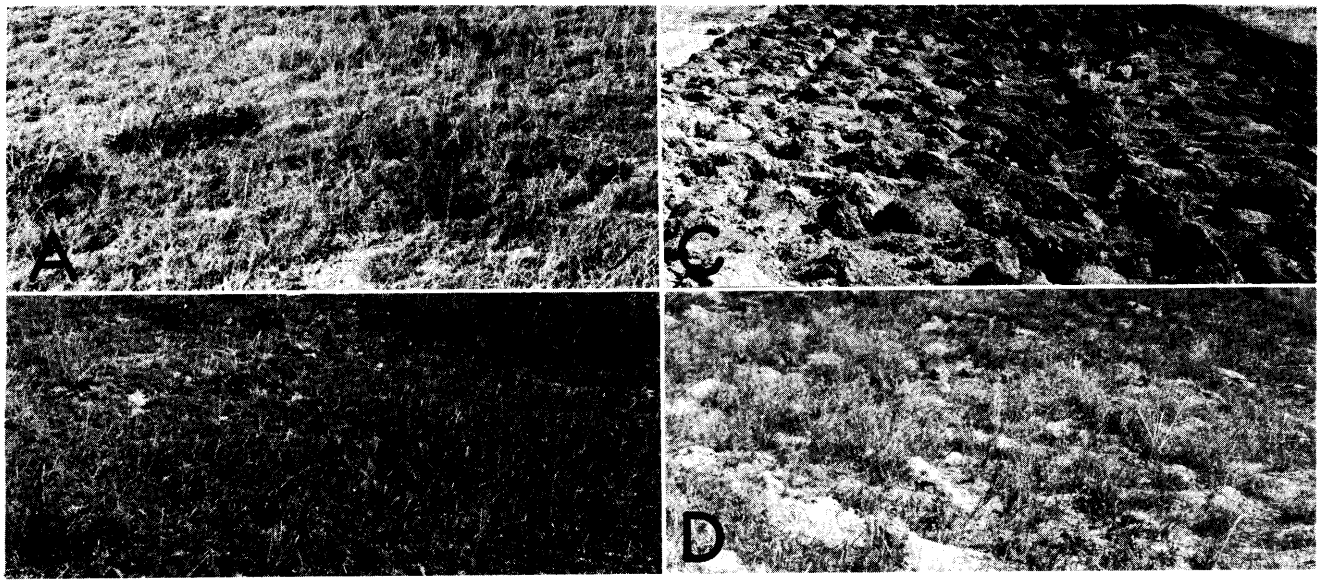


**Fig. 1.** *Check and moldboard plowed plots on a clayey range site, Durham Ranches, Inc., Gillette, Wyo. (A) check, fall 1967; (B) check, fall 1972; (C) moldboard plowed, fall 1967; (D) moldboard plowed, fall 1972. Note the western wheatgrass, cheatgrass, and rough soil surface in photo D.*

respectively, a good cover of native vegetation was present throughout the study on both sites (Fig. 1, A & B). Plains prickly pear and big sagebrush were scattered throughout the plots. Above-average spring precipitation in 1971 accounted for the higher than average perennial grass yields on the clayey site. Abnormally high precipitation in August, 1972, was not as effective in increasing perennial grass yields on the clayey site as it was on the sandy site.

*Clayey Site*

Total herbage yield from the check plots averaged 454 lb/acre over the 5-year period, significantly less than from M-plow, rotovator, and atrazine treatments (Table 2). Annual herbage yields fluctuated in relation to the April, May, and June precipitation. Blue grama was the dominant grass species. The proportions of total herbage contributed by the blue grama and western wheatgrass changed directions over the 5-year period. Blue grama decreased from 65% and 68% in the first 2 years to 42% and 41% of the total composition in the last 2 years. Western wheatgrass increased from 18% in each of the first 2 years to 28% and 30% in the last 2 years. Regression analysis showed the reversal in percentage composition by blue grama and western wheatgrass to total herbage was highly significant. Annual grasses were of no importance. Forbs (annual and perennial) were influenced by precipitation patterns among years and contributed a maximum of 9% of total herbage in 1971.

*Sandy Site*

Not all the broadleaved forbs were killed by the aerial spraying of 2,4-D in June, 1970; 55 lb/acre were present when the subplots were harvested in the fall.

Total herbage yield from the check plot at this site averaged 523 lb/acre over the 5-year period, significantly less than those from the M-plow, D-plow, and atrazine treatments (Table 3). Total herbage increased after the spraying with 2,4-D in 1970. Blue grama was the dominant grass, accounting for 30% to 58% of the total composition. Percentage composition of western wheatgrass was important only in 1971. Regression analysis showed that the changes in percentage composition by the blue grama and western wheatgrass was not significant. Needleandthread fluctuated in the percentage of total composition, but in 1972 accounted for 38% of the total. The miscellaneous forbs component decreased from 31% of the total vegetative composition in 1968 to 4% in 1971.

**Table 2. Yields (lb/acre) of western wheatgrass, blue grama, Sandberg bluegrass, dryland sedges, annual grass, forbs, total perennial grass, and the total forage from mechanically and chemically treated clayey range site at the Durham Ranches, Inc., Gillette, Wyo. 1968-1972.**

| | Treatment | | | | | | |
|---|---|---|---|---|---|---|---|
| Species and year | Check | Moldboard plow | Disc plow | Rotovator | Blade | Atrazine | Year mean |
| Western wheatgrass | | | | | | | |
| 1968 | 83 | 1 | 92 | 66 | 79 | – | 53$^{c}$ |
| 1969 | 52 | 99 | 146 | 206 | 90 | – | 99$^{c}$ |
| 1970 | 112 | 134 | 421 | 479 | 221 | 10 | 230$^{b}$ |
| 1971 | 164 | 328 | 636 | 779 | 200 | 52 | 360$^{a}$ |
| 1972 | 152 | 421 | 476 | 459 | 175 | 14 | 283$^{b}$ |
| Mean | 113$^{bc}$[1] | 198$^{b}$ | 354$^{a}$ | 398$^{a}$ | 153$^{b}$ | 15$^{c}$ | |
| Blue grama | | | | | | | |
| 1968 | 292 | 15 | 65 | 138 | 161 | 380 | 175$^{c}$ |
| 1969 | 195 | 113 | 124 | 294 | 162 | 328 | 203$^{c}$ |
| 1970 | 248 | 20 | 100 | 233 | 221 | 972 | 300$^{b}$ |
| 1971 | 245 | 10 | 53 | 190 | 308 | 1620 | 404$^{a}$ |
| 1972 | 206 | 12 | 66 | 118 | 190 | 1056 | 275$^{b}$ |
| Mean | 237$^{b}$ | 34$^{d}$ | 82$^{cd}$ | 195$^{bc}$ | 208$^{b}$ | 871$^{a}$ | |
| Sandberg bluegrass | | | | | | | |
| 1968 | 7 | – | – | 2 | 8 | – | 3$^{c}$ |
| 1969 | – | – | – | 2 | 6 | – | 1$^{c}$ |
| 1970 | 4 | 7 | 24 | 27 | 45 | – | 18$^{b}$ |
| 1971 | 52 | 6 | 25 | 24 | 63 | – | 28$^{a}$ |
| 1972 | 55 | 7 | 13 | 3 | 30 | 2 | 18$^{b}$ |
| Mean | 24$^{ab}$ | 4$^{c}$ | 12$^{bc}$ | 11$^{c}$ | 30$^{a}$ | 1$^{c}$ | |
| Dryland sedges | | | | | | | |
| 1968 | 16 | – | – | 8 | 15 | – | 6$^{a}$ |
| 1969 | 5 | – | – | 6 | 4 | – | 3$^{a}$ |
| 1970 | 28 | 2 | 11 | 13 | 15 | – | 12$^{a}$ |
| 1971 | 18 | 9 | 19 | 15 | 29 | 3 | 16$^{a}$ |
| 1972 | 30 | 2 | 15 | 17 | 39 | 7 | 18$^{a}$ |
| Mean | 19$^{a}$ | 2$^{c}$ | 9$^{bc}$ | 11$^{ab}$ | 20$^{a}$ | 2$^{c}$ | |
| Forbs | | | | | | | |
| 1968 | 4 | 216 | 50 | 10 | 19 | – | 50$^{a}$ |
| 1969 | 24 | 946 | 171 | 69 | 39 | – | 208$^{a}$ |
| 1970 | 38 | 1371 | 295 | 122 | 63 | – | 315$^{a}$ |
| 1971 | 54 | 708 | 322 | 99 | 75 | 62 | 220$^{a}$ |
| 1972 | 41 | 381 | 196 | 38 | 54 | 132 | 140$^{a}$ |
| Mean | 32$^{b}$ | 724$^{a}$ | 209$^{b}$ | 67$^{b}$ | 50$^{b}$ | 39$^{b}$ | |
| Annual grasses | | | | | | | |
| 1968 | – | – | – | – | – | – | – |
| 1969 | – | – | – | – | – | – | – |
| 1970 | 4 | 15 | 2 | 7 | 1 | 11 | 8$^{b}$ |
| 1971 | 3 | 19 | 23 | 40 | 3 | 7 | 19$^{b}$ |
| 1972 | 12 | 88 | 38 | 58 | 14 | 63 | 55$^{a}$ |
| Mean | 4$^{a}$ | 24$^{a}$ | 13$^{a}$ | 21$^{a}$ | 4$^{a}$ | 16$^{a}$ | |
| Total perennial grass | | | | | | | |
| 1968 | 431 | 16 | 157 | 207 | 248 | 380 | 240$^{c}$ |
| 1969 | 256 | 213 | 270 | 501 | 258 | 328 | 304$^{c}$ |
| 1970 | 375 | 165 | 556 | 738 | 481 | 988 | 550$^{b}$ |
| 1971 | 515 | 345 | 715 | 994 | 571 | 1703 | 807$^{a}$ |
| 1972 | 413 | 440 | 656 | 580 | 395 | 1074 | 578$^{b}$ |
| Mean | 398$^{c}$ | 236$^{d}$ | 453$^{c}$ | 604$^{b}$ | 391$^{c}$ | 895$^{a}$ | |
| Total herbage | | | | | | | |
| 1968 | 449 | 232 | 207 | 225 | 282 | 380 | 296$^{d}$ |
| 1969 | 285 | 1159 | 442 | 576 | 301 | 328 | 515$^{c}$ |
| 1970 | 445 | 1553 | 864 | 881 | 567 | 999 | 885$^{ab}$ |
| 1971 | 590 | 1082 | 1079 | 1148 | 678 | 1775 | 1058$^{a}$ |
| 1972 | 499 | 912 | 815 | 693 | 503 | 1277 | 783$^{b}$ |
| Mean | 454$^{d}$ | 988$^{a}$ | 681$^{cd}$ | 704$^{bc}$ | 466$^{d}$ | 952$^{ab}$ | |

[1] Means among treatments and years with the same letters are not significantly different at the 5% level.

### Moldboard-Plowed Treatment

The native sod was plowed about 4 inches deep at the clayey site and 5 inches at the sandy site using a two-bottom M-plow. The furrow slice was turned over and left with no further treatment. Plants not covered with soil soon died because roots and exposed tops dried out. After plowing, the soil surface was rough, and remained so until livestock were permitted to graze the experimental area 2 years later (Fig. 1, C & D).

Western wheatgrass increased slowly, and by the fourth year (1971) was conspicuous on both sites. A few scattered plants of blue grama were present on both sites. Dominant annual forbs present on both sites were tansy mustard (*Descurainia pinnata*) and green pepperweed (*Lepidium densiflorum*). Abundance of annual forbs varied with years. Russian thistle (*Salsola kali*) was present on both sites, particularly the first and second year after treatment. Slimleaf goosefoot (*Chenopodium leptophylum*) was important the first 2 years of the study. Plains Bahia (*Bahia oppositifolia*), a perennial forb, was the dominant forb on the clayey site; forb dominance varied on the sandy site. The first 2 years, scarlet globemallow (*Sphaeralcea coccinea*) was dominant, and by the fifth year fringed sagewort (*Artemisia frigida*) was dominant.

### *Clayey Site*

Over the 5-year period, total herbage from plots treated with the moldboard plow averaged 988 lb/acre (Table 2) which was significantly greater than for all but the strip-sprayed atrazine treatment. Western wheatgrass was the dominant perennial grass, and by the fifth year accounted for 46% of the total composition exceeding miscellaneous forbs. Annual grasses increased in importance after the third year to almost 10% of the total composition by the fifth year. By the end of the fifth year, much bareground remained on this treatment. Vigorous plants of western wheatgrass, annual and perennial forbs, and cheatgrass were scattered throughout the plots.

### *Sandy Site*

Total herbage from the moldboard-plowed plots averaged 1004 lb/acre for the 5 years (Table 3). This was significantly greater than production from the check and blade plots. Western wheatgrass was the dominant perennial grass and ranged from 5% to 61% of the total

**Table 3. Yields (lb/acre) of western wheatgrass, blue grama, Sandberg bluegrass, dryland sedges, annual grass, forbs, total perennial grass, and total forage from mechanically and chemically treated sandy range site at the Durham Ranches, Inc., Gillette, Wyo. 1968-1972.**

| Species and year | Treatment | | | | | | |
|---|---|---|---|---|---|---|---|
| | Check | Moldboard plow | Disc plow | Rotovator | Blade | Atrazine | Year mean |
| Western wheatgrass | | | | | | | |
| 1968 | 10 | 19 | 7 | 12 | 5 | – | 9$^{c}$ |
| 1969 | 16 | 51 | 28 | 68 | 14 | – | 30$^{c}$ |
| 1970 | 24 | 92 | 97 | 216 | 76 | – | 84$^{c}$ |
| 1971 | 59 | 996 | 574 | 597 | 96 | 76 | 400$^{a}$ |
| 1972 | 42 | 619 | 526 | 419 | 129 | – | 289$^{b}$ |
| Mean | 30$^{c}$[1] | 355$^{a}$ | 246$^{ab}$ | 262$^{a}$ | 64$^{bc}$ | 15$^{c}$ | |
| Blue grama | | | | | | | |
| 1968 | 233 | 11 | – | 38 | 186 | 314 | 130$^{d}$ |
| 1969 | 182 | 4 | 64 | 30 | 227 | 762 | 211$^{c}$ |
| 1970 | 182 | 39 | 5 | 10 | 183 | 1125 | 257$^{bc}$ |
| 1971 | 307 | 52 | 25 | 144 | 380 | 1364 | 378$^{a}$ |
| 1972 | 239 | 21 | 9 | 99 | 261 | 1131 | 293$^{b}$ |
| Mean | 229$^{bc}$ | 25$^{d}$ | 21$^{d}$ | 64$^{cd}$ | 247$^{b}$ | 939$^{a}$ | |
| Needleandthread | | | | | | | |
| 1968 | 34 | – | – | – | 53 | – | 15$^{b}$ |
| 1969 | 55 | 2 | – | 3 | 27 | – | 14$^{b}$ |
| 1070 | 151 | 12 | 42 | 7 | 78 | – | 48$^{b}$ |
| 1971 | 68 | 18 | 37 | 69 | 121 | 7 | 53$^{a}$ |
| 1972 | 304 | 54 | 29 | 75 | 106 | 21 | 98$^{a}$ |
| Mean | 122$^{a}$ | 17$^{c}$ | 22$^{a}$ | 31$^{c}$ | 77$^{b}$ | 6$^{c}$ | |
| Dryland sedges | | | | | | | |
| 1968 | 21 | – | 8 | 3 | 17 | 3 | 9$^{b}$ |
| 1969 | 22 | 11 | 6 | 1 | 39 | 5 | 14$^{b}$ |
| 1970 | 30 | 4 | 4 | 8 | 60 | 9 | 19$^{ab}$ |
| 1971 | 63 | 10 | 4 | 27 | 62 | 13 | 30$^{a}$ |
| 1972 | 45 | 50 | 20 | 9 | 30 | 9 | 27$^{a}$ |
| Mean | 36$^{a}$ | 15$^{b}$ | 8$^{b}$ | 10$^{b}$ | 42$^{a}$ | 8$^{b}$ | |
| Forbs | | | | | | | |
| 1968 | 134 | 125 | 237 | 241 | 68 | 2 | 134$^{b}$ |
| 1969 | 40 | 1003 | 376 | 280 | 122 | – | 303$^{a}$ |
| 1970 | 55 | 590 | 649 | 326 | 112 | 21 | 292$^{a}$ |
| 1971 | 25 | 162 | 167 | 127 | 19 | 53 | 92$^{b}$ |
| 1972 | 49 | 32 | 321 | 155 | 42 | 246 | 141$^{b}$ |
| Mean | 60$^{b}$ | 382$^{a}$ | 350$^{a}$ | 225$^{ab}$ | 73$^{b}$ | 64$^{b}$ | |
| Annual grass | | | | | | | |
| 1968 | – | – | – | 207 | – | – | 3$^{c}$ |
| 1969 | – | – | 10 | 37 | – | – | 1$^{c}$ |
| 1970 | 39 | 133 | 109 | 56 | 54 | – | 65$^{c}$ |
| 1971 | 17 | 396 | 562 | 157 | 129 | 11 | 212$^{b}$ |
| 1972 | 41 | 491 | 755 | 375 | 60 | 91 | 302$^{a}$ |
| Mean | 32$^{b}$ | 340$^{ab}$ | 476$^{a}$ | 204$^{ab}$ | 81$^{b}$ | 203$^{b}$ | 102$^{b}$ |
| Total perennial grass | | | | | | | |
| 1968 | 291 | 29 | 7 | 50 | 264 | 314 | 159$^{d}$ |
| 1969 | 253 | 58 | 381 | 103 | 271 | 762 | 305$^{c}$ |
| 1970 | 367 | 156 | 144 | 256 | 395 | 1125 | 407$^{c}$ |
| 1971 | 473 | 1067 | 703 | 824 | 700 | 1447 | 869$^{a}$ |
| 1972 | 664 | 705 | 565 | 663 | 555 | 1153 | 717$^{b}$ |
| Mean | 409$^{b}$ | 403$^{b}$ | 360$^{b}$ | 379$^{b}$ | 437$^{b}$ | 960$^{a}$ | |
| Total herbage | | | | | | | |
| 1968 | 433 | 154 | 252 | 336 | 349 | 320 | 307$^{d}$ |
| 1969 | 314 | 1071 | 763 | 388 | 431 | 767 | 623$^{c}$ |
| 1970 | 490 | 882 | 907 | 647 | 621 | 1154 | 784$^{b}$ |
| 1971 | 579 | 1635 | 1436 | 1061 | 910 | 1523 | 1191$^{a}$ |
| 1972 | 798 | 1278 | 1661 | 1202 | 687 | 1498 | 1188$^{a}$ |
| Mean | 523$^{c}$ | 1004$^{ab}$ | 1004$^{ab}$ | 727$^{bc}$ | 600$^{c}$ | 1053$^{a}$ | |

[1] Means among treatments and years with the same letters are not significantly different at the 5% level.

composition. Annual and perennial forbs accounted for 67% to 94% of the total herbage the first 3 years, then declined to 2% the fifth year. The decrease in annual and perennial forbs was offset by an increase in annual grasses, which amounted to 24% and 38% of the total herbage the last 2 years of the study.

**Disc Plow Treatment**

The disc plow was more effective in tilling native sod on the sandy site than on the clayey site. Depth of tillage on the clayey site was between 3 and 4 inches, and ribs of soil 2 inches wide were left between the discs. Tillage depth was 5 to 6 inches on the sandy site, and tilled soil was left in a rough condition similar to the M-plow treatment (Fig. 2, A & B). Soil was moist to approximately 2 inches when tillage was performed, and this probably accounted for shallow tillage on the clayey site.

The first year after treatment, western wheatgrass was thinly scattered on the plots. Blue grama on undisturbed ribs of soil on the clayey site was vigorous and made good growth. Both sites had much bare ground and numerous forbs. Plains Bahia was the dominant forb on the clayey site; scarlet gaura (*Gaura coccinea*), scarlet globemallow, and Russian thistle were dominant on the sandy site. Other miscellaneous annual forbs were present, and amounts varied with years.

*Clayey Site*

Total herbage yield from disc-plowed plots over the 5-year period averaged 681 lb/acre, which was significantly less than the yield from the M-plow and atrazine treatments. Total perennial grass increased for 4 years and decreased the fifth year. Western wheatgrass accounted for most of the perennial grass. By the fifth year, western wheatgrass accounted for 58% of the total composition, whereas blue grama decreased from 31% to 8% of the total composition. Percentage composition of miscellaneous forbs ranged from 24% to 39% over the study period. Annual grasses were not important.

*Sandy Site*

Total herbage yield from the disc-plowed plots averaged 1004 lb/acre over the 5-year period, which was significantly more than the average yield from the check and from the blade treatment. Total herbage production increased each year, as did the annual grass. By the fifth year these plots appeared to be a dense stand of cheatgrass brome, with annual grasses accounting for 45% of the total composition. Western wheatgrass was vigorous and increased markedly after the third year. After treatment, blue grama never was a significant part of the total composition. Miscellaneous forbs accounted for 94% of the total composition the first year after treatment but decreased in importance after the third year; by the fifth year they accounted for 19% of the total composition.

**Rotovator Treatment**

Depth of tillage with a Howard rotovator was about 2 inches and left the soil surface smooth and relatively loose (Fig. 2, C & D). Western wheatgrass and blue grama were thinly scattered in the plots the first year after treatment. Average depth of western wheatgrass rhizomes was about 3 inches for both sites. Establishment of western wheatgrass resulting from pruning or redistribution of the rhizomes was minimal. This treatment should have been followed by a cultipacker to pack the loose surface soil to reduce the possibility of wind and water erosion.

Plains Bahia and slimleaf goosefoot were the dominant forbs on the clayey site the first year, whereas mustard species, Russian thistle, and scarlet globemallow were dominant on the sandy site. Both sites had a high percentage of bare ground the first year after treatment.

*Clayey Site*

Total herbage yield from the rotovator-treated plots averaged 704 lb/acre at this site, which was significantly more than the yield obtained from the check or blade treatments. Yield of total perennial

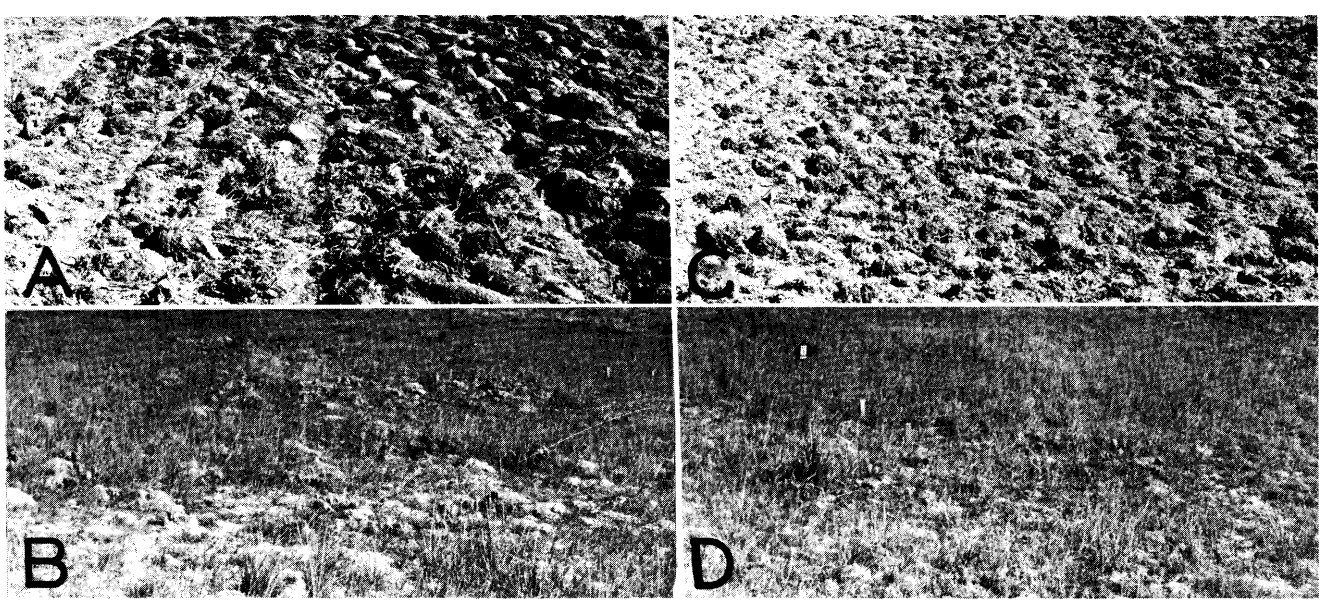


**Fig. 2.** *Disc plowed and rotovated plots on a clayey rante site, Durham Ranches, Inc., Gillette, Wyo. (A) disc plowed, fall 1967; (B) disc plowed, fall 1972; (C) rotovator, fall 1967; (D) rotovator, fall 1972. Note the stand of western wheatgrass in photos B and D, and the rough soil surface in photo B.*

grass ranged from 207 to 994 lb/acre, with western wheatgrass making the greatest contribution. Over the 5-year period the proportions of total herbage contributed by the blue grama and western wheatgrass were reversed. Blue grama decreased from 61% and 51% in the first 2 years to 16% and 17% in the last 2 years. Western wheatgrass increased from 29% and 36% the first 2 years to 68% and 66% the last 2 years. Regression analysis showed the reversal in percentage composition by the blue grama and western wheatgrass to total herbage was highly significant. The miscellaneous forbs component amounted to 12% and 14% of the total composition in 1969 and 1970, and then declined to 5% in 1972. Annual grasses were of no importance for the first 2 years, but then increased to 8% of the total composition the fifth year.

*Sandy Site*

Total herbage yields from the rotovator-treated plots at this site average 727 lb/acre, nearly the same as for the clayey site. Total herbage yield from the rotovator treatment was significantly less than from the atrazine treatment, but not significantly different from the other treatments.

Total perennial grass ranged from 50 lb/acre the first year after treatment to 824 lb/acre the fourth year after treatment. Western wheatgrass contributed from 24% to 84% of the total perennial grass. Western wheatgrass contributed only 4% of the total composition the first year after treatment, then increased to a high of 56% the fourth year, and 35% the fifth year. Regression analysis showed that changes in percentage composition by the blue grama and western wheatgrass was not significant. Needleandthread increased in the composition, particularly the last 2 years of the study. Miscellaneous forbs accounted for 72% of the total composition in 1969, and then declined to 13% in 1972. Annual grasses accounted for 62% of the total herbage the first year, were of minor importance the second and third year, and accounted for 31% of the total composition by the fifth year.

**Blade Treatment**

Plots were bladed to remove the blue grama, cactus and sagebrush. As pointed out by Vallentine (1971), only level lands can be bladed. Blading depth varied between ½ to 2 inches. The deeper cuts were on the outside areas of the plots. The year after treatment (1968) it was estimated that the blading had removed 60% of the vegetation on the clayey site and 70% on the sandy site (Fig. 3, A & B). The deeper cuts eliminated all vegetation, but not the rhizomes of the western wheatgrass. Stunted western wheatgrass, plains Bahia, and Russian thistle were the dominant species present in the deeper cuts on the clayey site, and scarlet globemallow was the dominant forb on the sandy site. Overall, blading reduced the vigor of the vegetation for 2 years.

*Clayey Site*

Total herbage yield from this treatment averaged 466 lb/acre, significantly less than the total herbage yield from the M-plow, rotovator, or atrazine treatment. Blue grama remained the dominant grass on these plots, although western wheatgrass increased markedly, particularly on the deeper cut areas. Western wheatgrass ranged from 28% to 39% of the total composition, whereas blue grama ranged from 57% in 1968 to 38% in 1972. Yield of perennial grass from the blade treatment was similar to that from the check. After the second year the forb component remained nearly the same. Annual grasses were of minor importance.

*Sandy Site*

Total herbage production from the blade treatment of this site averaged 600 lb/acre over the 5-year period. This was 22% more than was obtained from blading on the clayey site. Total herbage yield was significantly less than from the M-plow, D-plow, or atrazine treatment. Blue grama remained the dominant grass; western wheatgrass and needleandthread were codominant. Western wheatgrass increased from 1% of the total

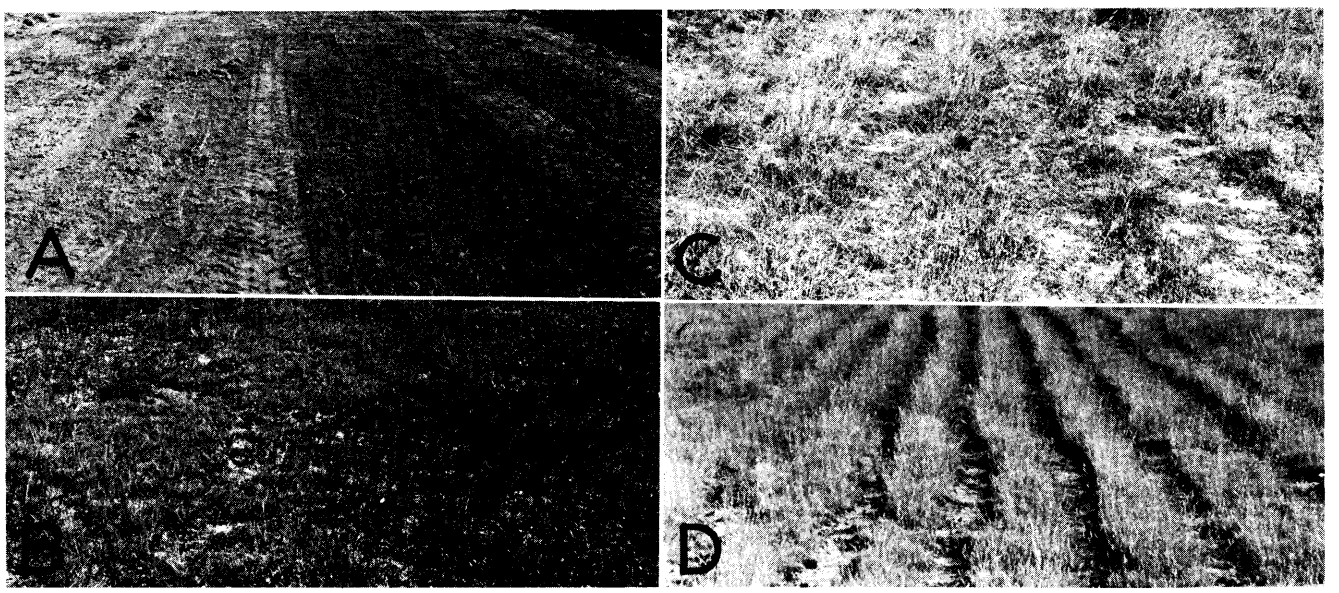


**Fig. 3.** *Bladed and atrazine strip sprayed plots on a clayey range site, Durham Ranches, Inc., Gillette, Wyo. (A) bladed, fall 1967; (B) bladed, fall 1972; (C) atrazine, spring 1968; (D) atrazine, fall 1972. Note the stunted western wheatgrass and blue grama in photo B, and the vigorous stand of blue grama with seed heads in photo D.*

composition the first year after treatment to 19% the fifth year. Most of the increase was from the deeper cut areas. Total perennial grass yield was similar to that of the check. Miscellaneous forbs were important in the total composition during the second and third year.

### Atrazine Treatment

Atrazine was applied on April 30, 1968, when western wheatgrass had about 2 inches of new growth, killing more than 60% of the vegetaion (Fig. 3, C & D). The western wheatgrass in the sprayed strip was killed, and the big sagebrush died the year after treatment. Three years after treatment only a few scattered plants of western wheatgrass were noted in the nonsprayed strip. Blue grama accounted for all the herbage on the clayey site and all but 6 lb/acre on the sandy site the first year after treatment. Thereafter, blue grama produced a profusion of seed heads and more basal herbage that remained green later in the season than on any of the other treatments. During the fifth year, annual forbs (plains plantain, stickseed, and fringed sagewort), cheatgrass and sixweeks-fescue, and scattered plants of blue grama were present in the sprayed strip, indicating that the atrazine was no longer effective.

Soil samples were collected in September 1970, 1971, and 1972 from the atrazine-sprayed strip at both sites for bioassay to determine the residual activity of atrazine. Soil samples were taken from 0- to 2-, 2- to 4-, and 4- to 6-inch depths, and oats were grown in the soil samples. Atrazine in the soil obtained from the 1970 sampling killed the oats. Oats grown in the soil collected in 1971 were not killed, but leaf tips died back and plants were not vigorous. Numerous leaf tips died when oats were grown in the soil collected in 1972, but otherwise the plants maintained vigorous growth.

By September 1972, the atrazine-treated strips averaged about 10 inches wide, indicating that the blue grama was reinvading the sprayed strip.

During the spring of 1971 and 1972, soil in the sprayed strip frost-heaved at both sites. Apparently, spring snows trapped by the blue grama saturated the soil and froze, thereby causing the frost heaving. In the spring of 1971, dead crowns of the blue grama in the sprayed strips were lifted by the frost heaving, but most of them settled with time. Frost heaving in the spring of 1972 removed most of the blue grama crowns, and erosion was accelerated.

#### *Clayey Site*

Total herbage for the 5-year period from the atrazine-treated plots at this site averaged 952 lb/acre. This was significantly more total herbage than was obtained from the check, D-plow, or blade treatments. During the last 3 years of the study blue grama was very productive, and was the dominant grass in all years. Blue grama accounted for 100% of the composition the first 2 years, and for 83% during the fifth year. Forbs and annual grasses increased during the fifth year.

#### *Sandy Site*

Total herbage production from atrazine-treated plots averaged 1,053 lb/acre over the 5-year period, and was significantly greater than the herbage yields obtained from check, rotovator, or blade treatments. Blue grama was the dominant grass in all years, and accounted for 99% of the composition in 1969, and 75% in 1972. Over the 5 years, the sandy site treated with atrazine produced 9% more perennial grass than did the same treatment on the clayey site. Annual grasses and forbs increased particularly during the last year of the study.

### Western Wheatgrass Culms

Western wheatgrass culms were counted on each treatment to compare treatment effects on western wheatgrass stands (Table 4).

**Table 4. Average number of western wheatgrass culms/ft² on the clayey and sandy rante sites. Durham Ranches, Inc., 1973.**

| Treatment | Sites | |
|---|---|---|
| | Clayey | Sandy |
| Check | 16.2$^{bc}$ [1] | 3.6$^{b}$ |
| Rotovator | 48.5$^{a}$ | 26.7$^{a}$ |
| Disc plow | 45.5$^{a}$ | 27.4$^{a}$ |
| Moldboard plow | 28.4$^{ab}$ | 30.1$^{a}$ |
| Blade | 34.7$^{ab}$ | 12.0$^{b}$ |
| Atrazine | 5.4$^{c}$ | 1.1$^{b}$ |

[1] Means among treatments with the same letters are not significantly different at the 5% level.

#### *Clayey Site*

The number of western wheatgrass culms on the rotovator, D-plow, M-plow, and blade treatments did not differ significantly on the clayey site. The average number of western wheatgrass culms ranged from 5.4 per square foot on the atrazine treatment to 48.5 per square foot on the rotovator treatment. Significantly more western wheatgrass culms were present on all tillage treatments than on the check or atrazine treatment.

#### *Sandy Site*

The check, blade, and atrazine-treated plots had significantly fewer western wheatgrass culms/square foot than did the other plots. The average number of culms per square foot ranged from 1.1 on the atrazine-treated plots to 30.1 on the M-plow.

Except for the M-plow treatment on the sandy site, the clayey site had more western wheatgrass culms per square foot regardless of treatment. The check on the sandy site had one-fifth as many western wheatgrass culms as did the check on the clayey site.

## Conclusions

Composition and herbage yields were influenced by renovation treatment, range site, and amount and distribution of the April-May-June precipitation.

Plots strip sprayed with atrazine produced significantly more total perennial grass than any of the other treatments. The first year after treatment blue grama was vigorous, produced a profusion of seed heads, and its herbage remained green later in the season. By the fourth year the residual activity of the atrazine had largely disappeared.

Kay (1971) reported that dry matter yields from a sward of red brome (*Bromus rubens*), Arabiangrass (*Schimus arabicus*), and red stem filaree (*Erodium cicutarium*) were increased sixfold by atrazine at 1 lb/acre in California. Forage crude protein and nitrate-nitrogen were also increased significantly. Atrazine at 1 lb/acre in combination with 40 lb N/acre applied in December or May was an effective method for increasing protein yield of shortgrass range in

Colorado (Houston and van der Sluijs, 1973).

Numerous annuals were present in the sprayed strip by the fifth year. These annuals utilize soil water and nutrients before the blue gtama starts growth and may crowd the blue grama out of the composition unless controlled.

Disc plowing and tilling with a rotovator may have potential as range renovation practices for improving species composition particularly on the finer textured soils. Severe tillage on a sandy range site appears to foster infestations of annual forbs and grasses. The marked increase of annual grass on the sandy site during the last 3 years of the study may have been influenced by the spraying of 2,4-D in 1970. Perhaps, the undesirable annuals could be controlled by herbicides. Evans et al. (1969) found that atrazine at 1 lb/acre controlled an average of 91% of the cheatgrass and 90% of the total weeds.

Blading or scalping with a road patrol appears to be of no value except to remove cactus and sagebrush. To increase the western wheatgrass, blading must remove the surface 2 inches or more of topsoil. Bare soil is subject to wind and water erosion and surface sealing, which delays secondary plant succession. Another undesirable feature is the problem of disposing of surface soil removed in the operation. If soil debris is windrowed, it becomes a seedbed for undesirable annuals, which may then spread. Strip blading may be of value where snow trapping is desired.

Moldboard plowing of native sod with no follow-up would not be recommended as a range improvement practice. The plowed sod should have been prepared and seeded with adapted species or at least packed mechanically or by livestock.

Yields of perennial grasses on the renovation treatments increased slower on the sandy site than on the clayey site. Annual forbs were dominant at first but were followed by the annual grasses, which are more troublesome. Moldboard-plow, disc-plow, and rotovator treatments increased western wheatgrass on both range sites by pruning and redistributing the western wheatgrass rhizomes. Reduced competition for available soil water and nutrients and more available nitrogen resulting from the disturbance of the native sod probably also were factors. Nichols (1969) stated that rhizomes of western wheatgrass plants may spread several feet in one favorable growing season, enabling recolonization of bare areas.

Light grazing the first 2 years may have been a better management tool than total deferment of grazing. Livestock trampling the tilled plots would have packed the soil and may have speeded up the establishment of vegetation on the area. To insure a stand, a desirable species should be seeded following a severe tillage treatment. This would be a small part of the cost of a renovation treatment.

Longevity of a renovation treatment will vary with range site and management. Once secondary succession has occurred from a severe tillage treatment, management will determine its longevity. Longevity of a herbicide treatment as used here may be 7 to 10 years, depending upon the range site, management, and encroachment of annual grasses.

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## Position Open

**FACULTY POSITION IN WILDLAND FIRE MANAGEMENT.** *Salary:* Position is to be on an 11-month basis with title and salary commensurate with experience. *Duties:* Teach upper division and graduate courses and do research dealing broadly with wildland fire behavior and management, including fuels management and the concepts of fire detection, suppression, and use. The appointment is to be approximately evenly divided between teaching and research. Share academic and administrative duties with the other faculty by serving on faculty and student committees. *Qualifications:* The applicant must hold a Ph.D. degree. Areas of expertise may include a firm foundation in wildland management, concepts and methods, and an understanding of wildland ecology, computer modeling, and optimization techniques. The candidates should also have knowledge of, and interest in, fire as a field of research. *Date:* The position is available to be filled as soon as the appointee is available. Applications will be accepted until September 1, 1975. *Applications:* Applicants should forward a letter of application, together with transcripts, copies of any publications, and names of three references to: **Professor Lee C. Wensel, Dept. of Forestry and Resource Management, University of California, Berkeley, California 94720.** The applicant should have letters of reference sent directly to the above address.