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Range Improvement Practices: Deteriorated Dense Clay Wheatgrass Range

J. T. Nichols

Bulletin 552

Range Improvement Practices on DETERIORATED DENSE CLAY WHEATGRASS RANGE in Western South Dakota

General view of study area in 1965 showing excellent range condition. Compare with same area in 1962, figure 4, page 12.

Agricultural Experiment Station
South Dakota State University, Brookings
in cooperation with
Agricultural Research Service, USDA

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Range Improvement Practices on Deteriorated Dense Clay Wheatgrass Range in Western South Dakota

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INTRODUCTION

Drought and overgrazing have a devastating effect on range, often causing the deterioration of valuable range resources which in turn results in economic hardships for the livestock producer. When this occurs, decisions are often necessary to determine how to regain or increase production. To make rational decisions for range improvement, knowledge is needed about how a particular range will respond to different range improvement practices and to which sites they are applicable.

The entire Great Plains Region is known for extreme temperature and precipitation fluctuations from the long term average. For example, precipitation at the U.S. Irrigation and Dryland Field Station, at Newell, in western South Dakota, has averaged 15.54 inches from 1908 through 1966, and has varied from a high of 28.31 inches in 1946 to a low of 6.64 inches in 1911. During the last 68 years, annual precipitation was below 10 inches six times and below the long-term average of 15.54 inches 33 times. High temperatures commonly accompany low precipitation, causing greater losses of an already scanty supply of soil moisture, thus reducing the effectiveness of the precipitation that does fall. Droughts are a matter of record and can be expected to recur in the future.

Fluctuations in density and productivity of native grassland plants occur as a result of these climatic variations. When grazing is not extreme during times of climatic stress, the native vegetation usually does not deteriorate

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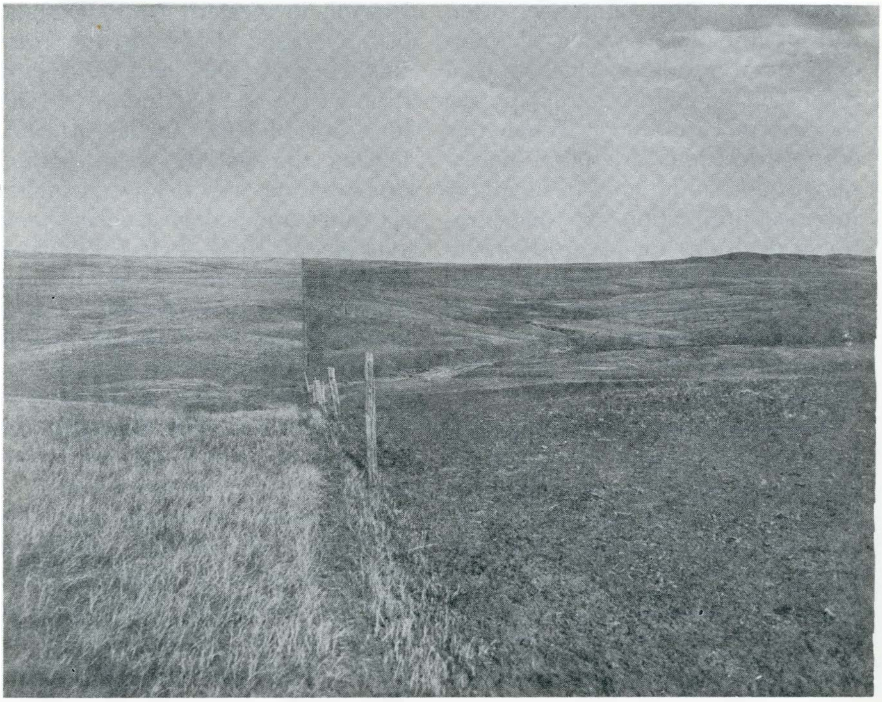
excessively and recovery is rapid. However, when abusive grazing practices are coupled with drought, the effect on the vegetation can be severe, often resulting in nearly complete denudation of the soil surface. This condition is especially prevalent on dense clay range of Western South Dakota (figure 1).

The years 1959-1961, were extremely dry in western South Dakota (figure 2). This, in conjunction with overgrazing, resulted in many areas of extremely deteriorated range. In some instances, natural recovery was questionable. Studies to determine methods of returning these ranges to productivity, were conducted in two experiments on 160 acres of range leased from Dale Richards, Newell. In 1962 studies began on several mechanical and seeding practices. By 1963 it was obvious that natural recovery was possible so an additional investigation was initiated with 2,4-D and nitrogen to determine if the rate of recovery could be accelerated.

Figure 1. Fence-line contrast showing the effect of drought and over grazing on a Dense Clay Range Site, Butte County, South Dakota, May 1960. Moderate degree of use (left), and extremely heavy use (right). (SCS Photo).



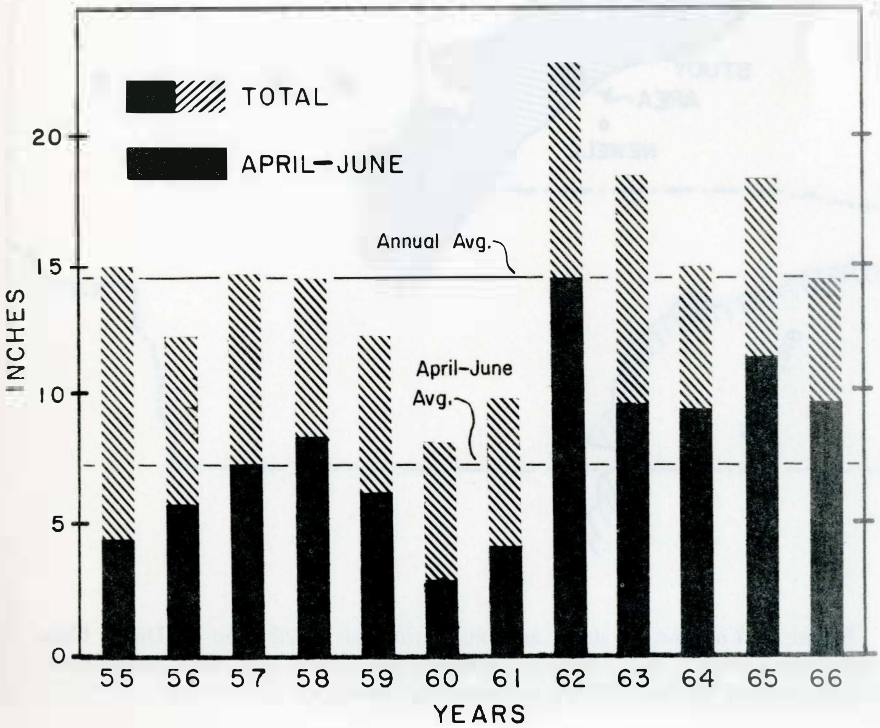
Description of Study Area

The study area, 12 miles northeast of Newell on a Dense Clay Range Site, is typical of about half a million acres in western South Dakota (figure 3). Most of this range resource is in Butte County with smaller acreages in Meade and Harding Counties. Similar range also occurs in southeastern Montana and northeastern Wyoming.

Soils

Soils were mapped and tentatively classified by the Soil Conservation Service as Bascom clay which is one of the most common soil series included in the Dense Clay Range Site. These soils are moderately deep, very slowly permeable, and fine textured. Clay content ranges from 65% to 70%. Soluble salt content and soil pH are not considered to be adverse to plant growth. Freezing and thawing breaks down the soil structure during winter, forming a loose friable soil surface 1 to 2 inches thick. Therefore, these soils are highly subject to wind and water erosion during the spring if not protected by adequate vegetation. During summer the soil becomes hard

Figure 2. Precipitation for 12 years at the U. S. Irrigation and Dryland Field Station, Newell, S. D., 1955-1966. Annual and April-June averages are for the 12 years shown. Long-term (1908-1966) annual average is 15.54 and the April-June average is 7.39.



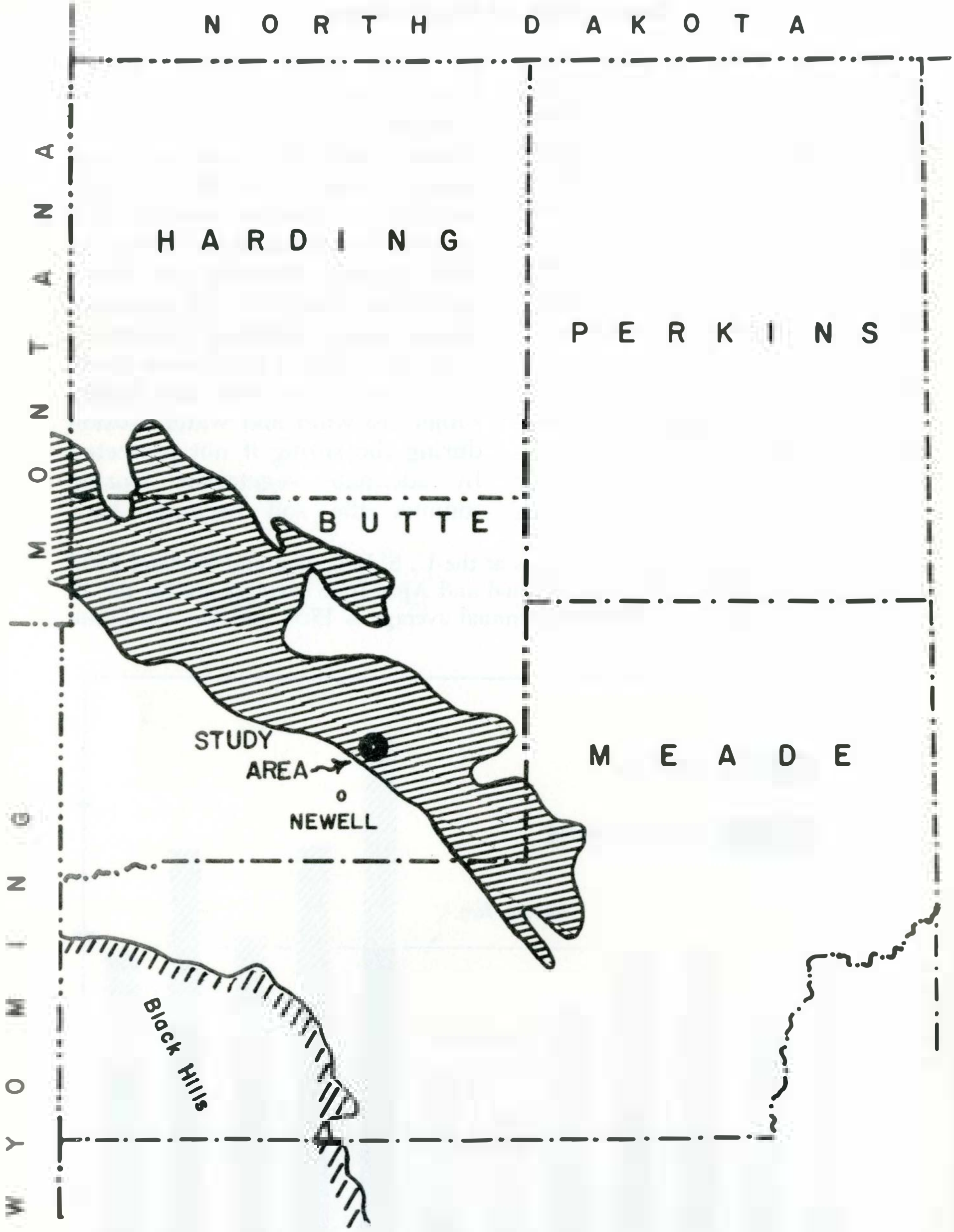


Figure 3. Location of study area and principal distribution of Dense Clay Range Sites in western South Dakota. (Distribution plotted from unpublished data, Soil Conservation Service, USDA, soil mapping survey.)

and compacted. Upon drying, cracks are formed and are often several feet deep and up to 3 inches wide. Physical characteristics generally make these soils unsuitable for cultivation and usually limit their use to production of native grasses for livestock grazing.

Vegetation

The dominant grasses are western wheatgrass (*Agropyron smithii*)[1] and green needlegrass (*Stipa viridula*). Western wheatgrass is by far the more abundant and contributes the most to productiveness of the site. Together with a small amount of forbs, these are the principal components of high condition range or climax vegetation. Other grasses found on this range site are of minor significance. Wild onion (*Allium textile*), false carrot (*Musineon divaricatum*) and wild parsley (*Lomatium spp.*) are relatively abundant early in the spring but by summer are dormant and not conspicuous. Other native perennial forbs are notably sparse on this site but were probably more abundant before intensive grazing by domestic livestock. As range condition decreases, western wheatgrass and green needlegrass become less vigorous and abundant and are replaced primarily by weedy vegetation such as annual saltbush (*Atriplex argentea*), common sunflower (*Helianthus annuus*), kochia (*Kochia scoparia*), Russian thistle (*Salsola kali*), curlycup gumweed (*Grindelia squarrosa*), and others. Pricklypear cactus (*Opuntia polyacantha*) also may become increasingly abundant on deteriorated ranges, but may serve a useful function when not overly abundant in that desirable grasses propagate from these sanctuaries when conditions improve.

Shortgrasses, buffalograss (*Buchloe dactyloides*) and blue grama (*Bouteloua gracilis*), which are common increasers on other range sites in western South Dakota, do not replace the mid-grasses, western wheatgrass and green needlegrass, under grazing pressure on the Dense Clay Site. Thus, the change that takes place in species composition from high to low range condition, is a shift from an abundance of western wheatgrass and greenneedle grass with a limited amount of forbs, to an annual weed type with a reduced stand of perennial grass. The recovery of deteriorated range follows a reverse pattern, rapidly changing from an annual weed stage to a vigorous cover of perennial mid-grasses, primarily western wheatgrass with smaller quantities of green needlegrass and forbs.

Methods

Two methods were used to evaluate the response of the vegetation to treatments. Frequency analyses were used as a comparative measure of the abundance of the various components of vegetation and their reaction to treatments. Each plot was sampled by recording the basal presence by species using a $\frac{3}{4}$-inch

[1]Nomenclature follows Hitchcock, 1950 for grasses, and Rydberg, 1932 for broadleaf plants.

loop placed at 1-foot intervals along a 100-foot tape. Data are presented as percentage frequency of occurrence. Production data were obtained from 1x20-foot clip plots, harvested with a sickle-bar mower at approximately an inch above ground level when the vegetation was near maturity. Samples were first sorted to remove residue from previous year's growth, then oven dried at 70° C., weighed, and converted to production in pounds per acre. Total deferment from livestock grazing was maintained on the "Nitrogen and 2,4-D" study. During the first 2 years of the "Mechanical and Seeding Range Improvement Practices," study, a moderate degree of late season use by sheep was permitted on a portion of the area. However, for purposes of this report, the influence of grazing was not considered or included since its effect was minimal.

Because a major portion of the broadleaf plants were weedy invaders, a single category, "weeds" is used with no distinction made between weedy plants and the more desirable broadleaved plants commonly referred to as "forbs" which are a natural component of high condition range. Data on grasses were combined in a category called "perennial grass" which includes both western wheatgrass and green needlegrass, with the latter making up only a minor part.

Mechanical and Seeding Range Improvement Practices

Ten replications of eight treatments were applied in 50x75-foot plots in the early spring of 1962 as outlined in table 1. The entire area was essentially devoid of vegetation when treatments started (figure 4). Following treatments earlier that spring, precipitation in April, May, and June was far above average (figure 2). Initially, pits and furrows retarded runoff and good stands were obtained from seeding. However, as the rain continued furrows and pits silted full and eroded away destroying many of the new western wheatgrass seedlings (figure 5). Seeding with the Nisbet grass drill was an exception in that many seedlings survived. Both methods of seeding sweetclover established acceptable stands. Plots were not sampled in 1962, the year of treatment.

Range Recovery

Table 2 indicates the effect of different treatments on the percentage frequency of grasses and weeds for 3 years following treatment. Some response to treatments was evident in 1963, notably the increased frequency of grasses for the drilled western wheatgrass and what appeared to be a temporary small reduction of grasses caused by some treatments of listing and pitting. By 1965 the percentage frequencies of grasses and weeds were not sufficiently different to be able to attribute a beneficial response or deleterious effect to any particular treatment. Reproduction of western wheatgrass by rhizomes was very pronounced on all treatments result-

ing in rapid range improvement. The 1963 increase in abundance of western wheatgrass from seeding (treatment 8) was not apparent 2 years after treatment in 1964 when compared with the control plots.

Table 1. Description of range improvement practices applied April 1962.

Treatments	Implements	Spacing (inches)	Lb/A (pure live seed)
1. Control	—	—	—
2. Sweetclover,* broadcast	Nisbet grass drill, spouts free	----	2.5
3. Sweetclover, drilled	Nisbet grass drill	10	2.5
4. Pitted†	One-way with notched discs	16	—
5. Planted western wheatgrass	Flex-planter	36	1.6
6. Pitted and planted western wheatgrass in pits	One-way with notched discs and flex-planter	36	1.6
7. Listed and planted western wheatgrass in furrows‡	Lister and flex-planter	36	1.6
8. Drilled western wheatgrass	Nisbet grass drill	10	6.0

*Biennial sweetclover *(Melilotus officinalis)*.
†Pits approximately 54 inches long, 4 inches deep and 10 inches wide.
‡Furrows approximately 2-3 inches deep and 10 inches wide.

Table 2. Average percentage frequencies of perennial grass, sweetclover, and weeds as affected by different range improvement practices, 1963-65.

Treatments	1963			1964			1965		
	G*	C	W	G	C	W	G	C	W
1. Control	7.6abc†		35.6ab	36.0ab		9.9bc	34.4a		4.4a
2. Sweetclover, broadcast	9.2 bcd	1.6a	34.0ab	32.8ab	30.2a	7.6ab	34.6a	17.1a	1.7a
3. Sweetclover, drilled	9.3 cd	2.5a	32.2ab	26.4ab	37.5a	3.1a	34.5a	17.5a	2.5a
4. Pitted	4.2ab		26.6a	23.5a		15.3 c	31.3a		8.5b
5. Flex-plant western wheatgrass	8.0abc		37.6 b	34.8ab		9.4bc	33.5a		3.3a
6. Pitted and flex-plant western wheatgrass	7.8abc		29.6ab	35.1ab		10.9bc	35.2a		3.8a
7. Listed and flex-plant western wheatgrass	3.5a		31.5ab	30.6ab		12.5bc	32.5a		4.0a
8. Drilled western wheatgrass (Nisbet drill)	13.6 d		35.1ab	37.0 b		10.7bc	35.2a		2.9a
Average	7.9	2.1	32.8	32.3	33.9	9.9	33.9	17.3	3.9

**G*=Grass (western wheatgrass and green needlegrass), *C*=sweetclover, *W*=weeds (all broadleaf plants except clover in treatments 2 and 3).
†Means of the same letter designation in the same column are not significantly different at the .05 level of probability, Duncan's Multiple Range Test.

Figure 4. Experimental treatments in the spring of 1962 were on range that was extremely deteriorated. Implement is a one-way plow with offset discs to form pits (treatment 4, table 1).

The most pronounced change in the vegetation was from 1963 to 1965, irrespective of treatments (table 2). This was caused by deferment plus improved growing conditions. In 1963 the vegetation was just starting to recover from its deteriorated condition and consisted primarily of weeds which had an average frequency over all treatments of 33% with grasses averaging only 8%. By July of 1964 the grasses had increased in frequency to an average of 32% with a corresponding decrease in the frequency of weeds to approximately 10%. Changes in abundance of grasses from 1964 to 1965 were small indicating that the grasses had made most of their recovery. Weeds continued to decline in frequency as abundance and vigor of grasses increased and by 1965 were not an abundant component of the vegetation.

Competition from sweetclover seeded in treatments 2 and 3 did not adversely affect the recovery of the grasses (table 2). Clover did, however, appear to act as a suppressant to weed populations in 1964 and 1965.

Considering all treatments and their effect on the recovery of the vegetation as indicated by frequency, very little benefit could be attributed to any treatment. Natural recovery by secondary succession was just as effective in the absence of treatment by 1964 as where treatments were applied.

Production

The various improvement practices did not appreciably increase the forage production expect for the plots which were seeded to sweetclover (table 3). Some increase in production, although not statisti-

Figure 5. Furrows holding water in the spring of 1962 (upper photo) and silted, eroded condition of pits after heavy spring rains (lower photo).

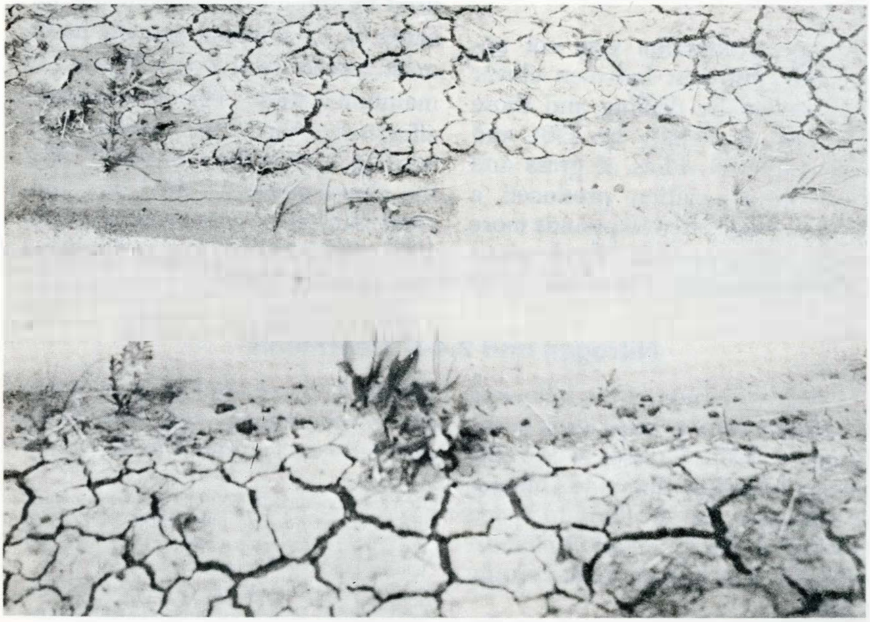


Table 3. Effect of range improvement practices on forage production. Pounds of oven-dry forage per acre, 1963-65.

Treatment	1963	1964	1965
1. Control	511a*	698abc	1063a
2. Sweetclover, broadcast†	2775b	949 c	1877b
3. Sweetclover, drilled†	3288b	949 c	1789b
4. Pitted	‡	505a	1020a
5. Flex-plant western wheatgrass	514a	558a	1055a
6. Pitted and flex-plant western wheatgrass	‡	643ab	1112a
7. Listed and flex-plant western wheatgrass	‡	611ab	1091a
8. Drill western wheatgrass (Nisbet grass drill)	646a	855 bc	1068a

*Means of the same letter for a given year are not significantly different at the .05 level of probability, Duncan's Multiple Range Test.
†Production includes both grass and clover.
‡Data not collected on these plots due to erosion destroying treatments in 1962, but collection continued in 1964 and 1965.

cally different, can be attributed to treatment 8 in 1963 and 1964 due to seedling establishment by drilling. By 1965, however, all treatments, except clover plots, were producing about the same. Erosion and siltation caused by heavy rain and lack of protective vegetation reduced the effectiveness of treatments 4, 6 and 7.

Forage production was not appreciably different between clover plots seeded by drilling and those broadcast, especially by 1964 and 1965 (table 3). Plots of grass and clover in association produced a 3-year average of 1,180 pounds more forage per acre than check plots. Grass production alone on plots seeded to clover was 361 pounds more per acre in 1965 than from plots where clover was not growing. Thus, the increase in total forage production was not all attributable to clover forage, but was at least partly a result of the beneficial effect of nitrogen supplied by clover and used by the grass. Sweetclover, because of its biennial growth habit, must reseed itself every 2 years to maintain a stand. This has occurred effectively since the initial 1962 seeding. Late in the summer of 1964, the clover seedlings died but sufficient hard seed was available from 1963 seed production to establish a new stand in 1965[2].

Nitrogen and 2,4-D Treatments[3]

Weeds were numerous following an abundance of precipitation in the spring of 1962. Grasses were only starting to regain vigor and colonize barren areas. In an effort to speed up range recovery, an additional experiment was started in the spring of 1963.

Four levels of nitrogen (0, 30, 60, 120 lb/A) were applied in all possible combinations with four levels of 2,4-D (0, ½, 1 and 2 lb/A), repli-

[2]Research on the clover plots has been continued and expanded to more fully evaluate the use of clover in western wheatgrass ranges and will be reported at a later date.

[3]Reported by Nichols and McMurphy (1969), but included here to summarize treatment effects on this type of range.

cated 6 times in plots 14x45 feet. Nitrogen was applied as ammonium nitrate on March 28 and the 2,4-D on May 24, both only once in 1963. The objectives were to use 2,4-D to reduce weed competition and use nitrogen to stimulate the recovery rate of the native grasses.

In 1963, approximately 79% of the total vegetation consisted of weeds, 80% of which were annuals. Higher rates of 2,4-D were the most effective in reducing the abundance of weeds (table 4). By 1964 and 1965, differences in the abundance of weeds were minimal between sprayed and nonsprayed plots and among rates of 2,4-D. By 1964, the grasses had gained sufficient vigor to suppress annual weed growth by being effective competitors for available soil moisture. An abundance of annual weeds on rangeland is often a response to seasonal soil moisture being in excess of what the perennial grasses can effectively utilize.

Range Recovery

The response of the perennial grass to the highest rates of 2,4-D and nitrogen, alone and in combination, is illustrated in figure 6. Response to treatment was most pronounced in 1965, three growing seasons after treatmen when the 2 lb/A rate of 2,4-D in combination with 120 lb/A of nitrogen increased the frequency of perennial grass by 10% over the control. A combination of nitrogen and 2,4-D was more effective than when either treatment was applied alone. Generally, by 1965 spraying to suppress competition from weeds permitted a more rapid increase in the abundance of grass. Nitrogen accelerated the recovery of grasses so that 2,4-D and nitrogen acting in combination brought about a faster recovery than non-treated plots. Although some response to treatments was evident, the use of nitrogen and 2,4-D alone or in combination does not appear feasible on this type of range. This is especially evident in view of the rapid range recovery brought about by grazing deferment and favorable climatic conditions as well as when considering the small differences between the control and plots where treatments were applied.

Table 4. Effect of spraying with 2,4-D on the percentage frequency of weeds, 1963-1965. Includes both annual and perennial weeds over all levels of nitrogen.

2,4-D lb/A	1963[1]	1964	1965
0	21.3	1.3	3.2
½	9.9*	0.4*	1.9*
1	4.2*	0.1*	2.1
2	1.5*	0.6*	2.2

[1]Data collected on July 10, following treatment May 24.
*Significantly different from the control ($P < 0.05$), Dunnett, 1955.

Production

Grass production was increased by nitrogen and 2,4-D treatments (table 5). Higher rates of nitrogen (60 and 120 lb N/A) increased production the most and continued to increase production for 2 years after application, whereas at the 30 lb rate no residual effect was evident. In 1963 the grasses had not recovered sufficiently from the effects of drought and overgrazing to respond fully to either treatment. By 1964, although the abundance of grasses had increased as indicated by figure 6, production was lower than the previous year due to a less favorable

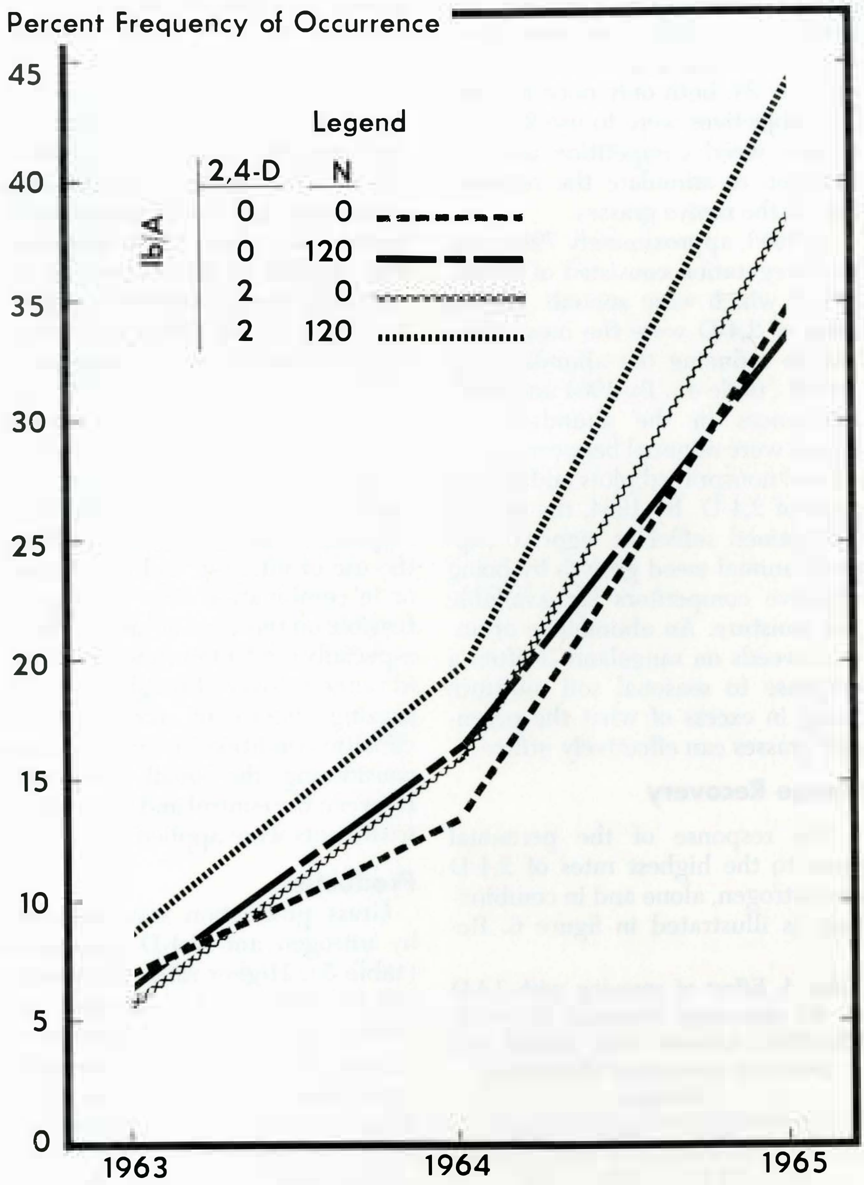


Figure 6. Perennial grass frequency as affected by 2,4-D and nitrogen. In 1965, the mean value for 2 lb/A 2,4-D and 120 lb/A N significantly different ($P<0.05$) from the control (Dunnett, 1955). All treatment means not significantly different from the control, 1963-1965.

Table 5. Perennial grass production as influenced by 2,4-D and nitrogen treatments (lb. oven-dry forage/A).

Treatments Nitrogen[2] lb/A	2,4-D lb/A[1]					
	1963		1964		1965[3]	
	0	2	0	2	0	2
0	249	426	346	335	996	1221
30	406	571	259	377	969	1247
60	755*	747	336	442	1006	1554
120	519	794*	431	531	1235*	1906*
Average	482	635	343	421	1052	1482

[1]Significant ($P<0.05$) response to 2,4-D in 1963 and 1965 but not in 1964.
[2]Significant response ($P<0.05$) to nitrogen in 1963, 1964 and 1965.
[3]Nitrogen x 2,4-D interaction significant ($P<0.01$) in 1965 but not in 1963 and 1964.
*Significantly different ($P<0.05$) from the 0 rate of nitrogen within a column, Dunnett (1955).

early spring growing season. Forage production in 1965 reflects the accumulative effects of protection from grazing for 3 years, plus treatment effects of nitrogen and 2,4-D. Plots which were sprayed in 1963 continued to produce more than non-sprayed plots by 430 lb/A in 1965 when averaged over all rates of nitrogen. This indicates that reducing forb populations by spraying benefited the grasses sufficiently the first year to be expressed in increased yield 2 years after treatment. Table 4 suggests that weeds were not numerous enough in any treatment to be critical in 1964 and 1965 and that any beneficial effect would be related to 1963 differences.

Total perennial grass production for the 3 years was increased over the control by 391 pounds per acre in response to 2,4-D (2 lb/A) and by 594 pounds per acre by the 120 lb/A rate of nitrogen. The combination of these two treatments increased production over the control by 1,640 pounds of forage per acre.

The use of nitrogen and 2,4-D to improve range condition and increase production would be difficult to justify economically when based on the results of this study. With a more favorable price structure and if responses persisted, treatments could approach economic feasibility. However, the principle appears valid for improving range condition and increasing range productivity by weed control with 2,4-D and nitrogen fertilization to stimulate the grasses. Under different circumstances, such as high infestations of perennial weeds which would not decrease by natural processes and/or extremely low soil nitrogen, it is theorized that response to treatments would be greater.

Natural Recovery by Secondary Succession

One of the most significant and perhaps important aspects of both studies was the rapid recovery of vegetation by natural secondary successional processes when released from grazing pressure and when

adequate precipitation was received. Even in the absence of range improvement practices (control plots) natural recovery was rapid. This illustrates the fact that deferment from grazing can be used as one of the most effective range improvement practices on the type of range described in this study.

Changes in species composition were pronounced from the start of the investigation, when a completely deteriorated range existed, to 1965 when the study areas had recovered to high range condition. In 1963, weeds were the major components of the vegetation, constituting 82% of the composition with

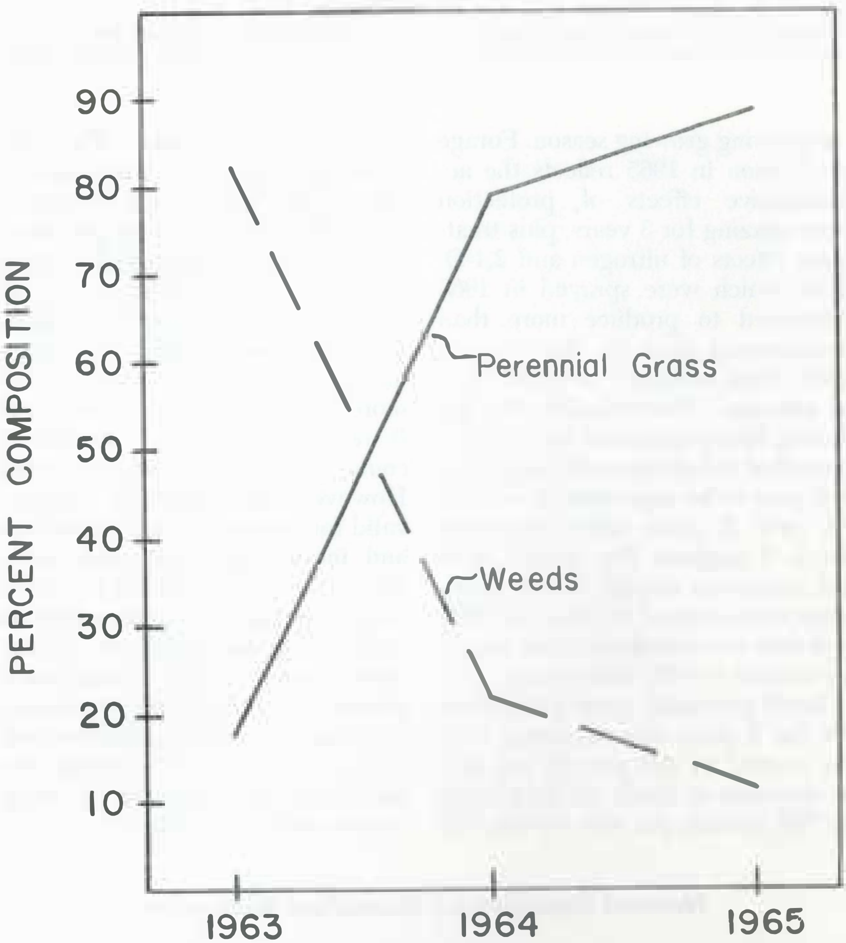


Figure 7. Changes in percent composition of perennial grass and weeds over a 3-year period. (Data from control plots of the "mechanical and seeding range improvement practice" study.)

western wheatgrass and green needlegrass making up about 18% (figure 7). By the end of the 1964 growing season, nearly a complete reversal was evident in that perennial grasses made up 78% of the composition and weeds were reduced to 22%. In 1965 grasses continued to increase, and the percentage of weeds continued to decline showing a further improvement in range condition. Using the system of range condition classification proposed by Dyksterhuis (1949) and used by the Soil Conservation Service (Soil Conversation Service, 1962) the study area had changed from very poor range condition in 1962 to excellent range condition in 1964, over a period of 3 growing seasons. A comparison of figures 4 and 8 illustrates the change in range condition that took place.

The rapid improvement in range condition was accomplished vegetatively by rhizomes. Rhizomes, spreading several feet in one favorable growing season (figure 9), enabled western wheatgrass to recolonize areas which were formerly devoid of vegetation or producing only weeds. Recovery of western wheatgrass range is much more rapid than where the dominant species reproduce by means of seeds. Mueller (1941) working in Nebraska found that rhizomes of western wheatgrass elongated 7 feet in one growing season and that over a 2-year period 600 feet of rhizomes were produced in a square meter area.

Failure to produce a significant increase in the rate of range recovery by seeding western wheatgrass can be attributed to the fact that re-

Figure 8. General view of study area in 1965 showing excellent range condition. Compare with same area in 1962, figure 4.

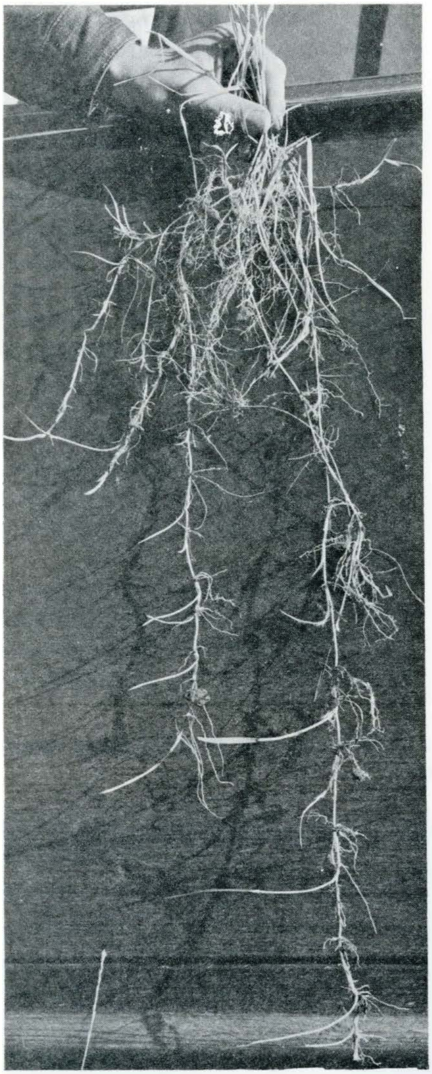


Figure 9. Rhizome growth of one western wheatgrass plant made during the growing season of 1962. Twenty-two new shoots were developed. (SCS Photo.)

colonization of barren areas by rhizomes was just as rapid and probably more effective than seeding. Except where rhizomes are definitely known to be dead, seeding is of questionable value. Weaver (1938) has indicated that cultivated grain fields abandoned after 3 to 16 years of shallow tillage can be revegetated by western wheatgrass in 3 to 5 years. Rhizomes that were broken up by tillage, but not destroyed, developed rapidy when removed from competition with the grain crop. This illustrates that western wheatgrass rhizomes have the ability to remain viable even when growth is suppressed for some time, and helps to explain why western wheatgrass ranges have the ability to respond so rapidy to improved growing conditions when afforded the opportunity.

Summary and Conclusions

It is apparent that certain range improvement practices are more appropriate than others as a means of accelerating recovery and increasing production on Dense Clay Range Sites.

Each range site has certain characteristics of soils and vegetation which are sufficiently different from other sites to warrant separate classification, management and methods of range improvement. Therefore, interpretation and application of results of range improvement practices reported in this study should be limited to soils and vegetation typical of the Dense Clay Range Site.

Excellent growing conditions prevailed during the time of study, affording rapid range recovery and potential response to treatments. The following conclusions are drawn concerning range improvement practices for the Dense Clay Range Site in western South Dakota:

1. Recovery of deteriorated range following drought and overgrazing was pronounced when relieved from grazing pressure and adequate precipitation was received regardless of treatments. Range improvement by secondary successional processes was extremely rapid from an annual weed stage or poor range condition to high range condition consisting primarily of perennial grasses. This indicates that deferment from grazing alone can bring about a rapid recovery of deteriorated range, making this an effective range improvement practice on this type of range.
2. Seeding sweetclover into deteriorated range increased total forage production more than any other treatment. Natural reseeding was effective in maintaining a stand. Production was increased by the addition of clover forage, plus more grass produced by the stimulating effect of nitrogen supplied by the clover. This practice appears to be well suited to the Dense Clay Range Site.
3. Mechanical treatments such as pitting and furrowing are of questionable value on soils which become extremely loose on the surface due to freezing and thawing and when vegetation cover is lacking. The possibility exists that pits and furrows might retain their ability to retard runoff and not erode away if an adequate cover of vegetation were present when treatments are applied. However, in this study these practices were of no value.
4. Seeding of western wheatgrass was of little value due to sufficient residual wheatgrass plants which recolonized areas rapidly by means of rhizomes. Before seed-

ing it should be determined that rhizomes are dead or will not recover at an adequate rate.

5. The rate of range recovery was increased by spraying with 2,4-D to suppress weed competition when used in combination with nitrogen to stimulate grass recovery. However, when the major portion of the weedy plants are annuals, their abundance declines by natural successional processes as the grasses regain vigor, thus making spraying a questionable range improvement practice under these conditions.

6. Perennial grass production was increased by application of nitrogen. A more consistent and pronounced response was evident when applied in combination with 2,4-D.

7. The use of nitrogen and 2,4-D to improve range condition and increase production would be difficult to justify economically when based on the results of this study. With a more favorable price structure and if responses persisted, treatments could approach economic feasibility. Under different circumstances, such as high infestations of perennial weeds which would not decrease by natural processes and/or extremely low soil nitrogen, it is postulated that reponse to treatments would be greater.

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