Production Response of Native and Introduced Grasses to Mechanical Brush Manipulation, Seeding, and Fertilization

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Abstract

Effects of two mechanical brush manipulation treatments (rootplowing and front-end stacking) with and without grass seeding and with and without nitrogen fertilization on herbaceous forage production were investigated in the Rio Grande Plain of Texas. Total herbaceous production (4-year average) was 5,981 for rootplowing and 4,789 kg/ha for front-end stacking as compared with 2,178 kg/ha for the undisturbed control. The 4-year average yield of buffelgrass (*Cenchrus ciliaris* L. (L.) Link) seeded alone contributed 53% of total herbaceous production on plots with rootplowing, 73% on plots with front-end stacking, and 38% on control plots. The combined yield of three native species, pink pappusgrass (*Pappophorum bicolor* Fourn.), four-flower trichloris (*Trichloris pluriflora Fourn.*), and Arizona cottontop (*Digitaria californica* (Benth) Henr.), seeded as a mixture contributed 41% of the total herbaceous production on plots with rootplowing, 28% on plots with front-end stacking, and 11% on control plots. The application of 45 kg/ha nitrogen significantly increased total herbaceous production the season after application.

Population increases have caused concern about increasing needs for red meat as food source throughout the world. The key for increasing beef and wild game production is increasing native and introduced herbaceous plant production, thus making more food available to grazing animals and ultimately to man.

On the Rio Grande Plain in Texas, the invasion of woody plants and cacti has reduced available grass forage. About 85% (5.5 million ha) of the Rio Grande Plain rangeland supports at least a 20% brush canopy cover (U.S. Dep. of Agr. 1964). Conceivably, many range sites of the Rio Grande Plain are producing at only 25% of their forage potential, and much of the native rangeland of Texas is producing far below potential (Texas Conservation Needs Committee 1970).

Rootplowing, a mechanical manipulation practice that cuts off the brush below ground by means of a horizontal blade pulled behind a tractor, generally at a depth of 35 to 40 cm, has been highly effective in combatting dense stands of mixed brush. However, in low rainfall areas, the practice could destroy a large percentage of the desirable perennial grasses and cause the invasion of annual grasses and weeds (Fisher et al. 1959). Mathis et al. (1971) reported that in Throckmorton County, Texas, rootplowing decreased grass production for the next six growing seasons. In west Texas, Hughes (1966) reported more total production after rootplowing, but forbs and annual grasses constituted the major vegetation. In the coastal prairie of Texas, Powell and Box (1967) concluded that controlling brush with a minimum soil disturbance was the most reliable method for improving vegetative composition and increasing forage production. They also concluded that N fertilizer increased forage production, but also caused an increase in the amount of undesirable forage species.

Dodd (1968) reported that in the Rio Grande Plain, dragging followed by rootplowing resulted in the establishment of a relatively brush-free grassland with an increase in forage production.

Fisher et al. (1959) reported that seeding of grasses produced good stands of native and introduced grass species after rootplowing and disking in northwest Texas. However, on the Rolling and Southern High Plains, Jaynes et al. (1968) reported that seeding native grasses after rootplowing often resulted in unsatisfactory stands.

Front-end stacking, a recently introduced mechanical practice, has not been thoroughly evaluated. A front-end stacker is a modified dozer blade using a toothed, rake-like "stacker" with teeth 14 to 36 cm apart. The teeth pull up the plants by the roots. In the Coastal Prairie of Texas, Powell and Box (1967) found that scalping, a manipulation similar to front-end stacking, decreased herbage production.

In view of these inconsistent results of brush manipulation on forage production, we conducted this study to further evaluate the effects of rootplowing and front-end stacking with and without grass seeding and with and without N fertilization on herbaceous forage production on the Rio Grande Plains of Texas.

Materials and Methods

Study Area

The study area is on the southern edge of the Rio Grande Plain, about 38 km north of Rio Grande City, Starr County, Texas. Long-term average annual precipitation is 43 cm and is exceeded by potential evaporation four times (U.S. Dep. Commerce 1970). Most precipitation occurs as thunderstorms that are unevenly distributed both geographically and seasonally. Occasionally, tropical disturbances produce heavy fall rains; thus, September has the highest long term monthly rainfall average, with another rainfall peak in late May or early June from squall-line thunderstorms.

Summer temperatures are high, and daily maximum temperatures in July and August are usually 38°C or higher (U.S. Dep. Commerce 1970). Fall freezes occur 7 out of 10 years, and spring freezes occur 9

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out of 10 years. The average length of the growing season is 305 days (U.S. Dep. Commerce 1970).

The study area is a sandy loam range site with level to gently sloping topography (0 to 5%). The associated soil types are McAllen and Brennan sandy loams, which are soils with noncalcareous fine sandy loam surfaces and sandy clay loam subsoils. The Brennan series is a member of the fine-loamy, mixed, hyperthermic family of Aridic Haplustalfs; the McAllen series belong to the hyperthermic family of Ardic Ustochrepts. The fine sandy loam surface ranges from about 25 to 50 cm deep. Permeability of the subsoil is moderate. The water holding capacity and fertility of these soils are high; thus, this site has a high production potential.

The dominant woody plant species include cenizo (*Leucophyllum frutescens* (Berl.) I.M. Johnston), blackbrush acacia (*Acacia rigidula* Benth.), coyotillo (*Karwinskia humboldtiana* (R&S) Zucc.), coma (*Bumelia celastrina* H.B.K.), mesquite (*Prosopis glandulosa* Torr.), and capul (*Schaefferia cuneifolia* Gray). Brush density consists of about 4,900 plants/ha with 35% canopy cover.

Dominant grass species include Wright's threeawn (*Aristida wrightii* Nash.), Texas bristlegrass (*Setaria texana* Emery.), hooded windmill grass (*Chloris cucullata* Bisch.), and red grama (*Bouteloua trifida* Thrub.). Forb cover was sparse, with western ragweed (*Ambrosia psilostachya* D.C.), ragweed parthenium (*Parthenium hysterophorus* L.), rose palafoxia (*Palafoxia rosea* (Bush) Cory), and lazydaisy (*Aphanostephus skirrhobasis* (D.D.) Trel.) recurring as dominants.

Treatments

Mechanical treatments were established during June 1972 on native undisturbed brushland in poor condition due to overgrazing. A split-block design had main plots of two mechanical brush-manipulation treatments (rootplowing and front-end stacking) and an undisturbed control. Each replication or block consisted of three 2.4-ha strips, one strip each for rootplowing, front-end stacking, and the control. Each strip was divided equally into three 0.8-ha subplots, which were seeding treatments of (1) a single species, buffelgrass (*Cenchrus ciliaris* (L.) Link, at 2.2 kg/ha, (2) a mixture of five native grass species (Table 1), and (3) unseeded. Subplots were hand seeded between August 31 and September 6, 1972. Each subplot was split into two sub-subplots (0.4 ha each) with one receiving 45 kg/ha N and the other receiving no fertilizer. All treatments were replicated three times. Nitrogen (as ammonium nitrate) was applied about 1 year after seeding (August 1973). Thus, the experimental plot layout consisted of fifty-four 0.4-ha plots.

Table 1. Five native grasses seeded as a mixture and corresponding seeding rates.

Grass seed	Rate[1] (kg/ha)
Pink pappusgrass (*Pappophorum bicolor*)	0.4
Arizona cottontop (*Digitaria californica*)	0.7
Plains bristlegrass (*Setaria macrostachya*)	0.4
Two-flower trichloris (*Trichloris crinita*)	0.3
Four-flower trichloris (*Trichloris pluriflora*)	0.3

[1] Rates based on pure live seed.

A standard recording rain gauge was used to measure rainfall. Rainfall amounts recorded were 86, 60, 55, and 73 cm for 1973, 1974, 1975, and 1976, respectively.

All plots were deferred from domestic livestock grazing until January 1974. Then they were grazed from late spring to early summer and again in late fall each year. The number of animal units varied each year, but plots were grazed for 90, 140, and 135 days for 1974, 1975, and 1976, respectively, which was about 60% utilization each year.

Herbaceous forage production was determined by clipping all vegetation at ground level in twenty 0.5-m² quadrats on each subplot All grasses and forbs in each quadrat were identified, counted, and recorded. Each species was clipped separately and yields were determined by species. Vegetation samples were oven dried at 68°C, and yields were reported as oven-dried weight. Yields are accumulations of two harvests per year (June and November).

Soil infiltration measurements were determined in all subplots of one main plot replication with the technique described by Wiegand et al. (1966) using water from a nearby well containing 2,220 ppm total salts. Soil moisture before infiltration was determined gravimetrically.

During the study, soil moisture was determined by neutron scattering techniques (Stone et al. 1955). Access tubes were installed in all plots of one replication. Two tubes were located in each plot to a 90-cm depth. Soil moisture was measured weekly at 30-cm depth increments, and these data were converted to centimeters of water/30 cm of soil.

Plant nomenclature follows Gould (1969) and Correll and Johnston (1970). Data were analyzed statistically by the analysis of variance method (Cochran and Cox 1956).

Results

Before treatment, the study area supported a dense stand of

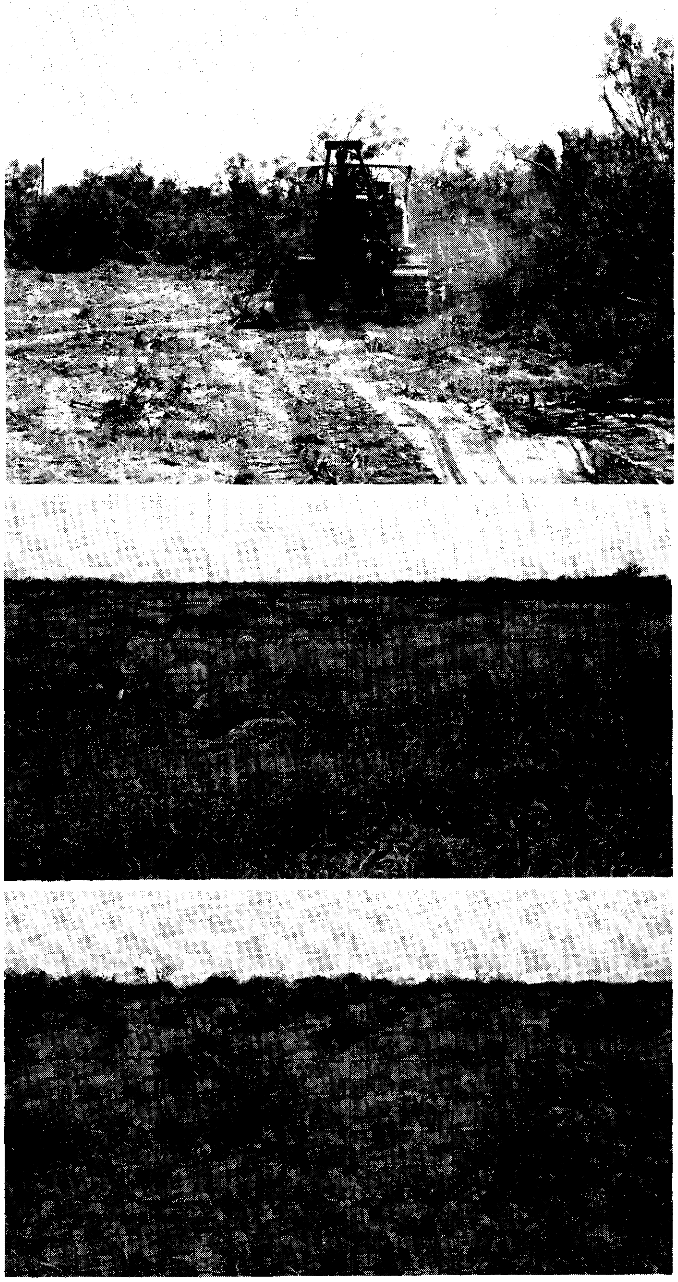

Fig. 1. *Vegetation condition in 1972 prior to mechanical brush manipulation (upper), 3 years after rootplowing and seeding to buffelgrass (center), and 3 years after front-end stacking and seeding to buffelgrass (lower).*

Table 2. **Effects of mechanical brush manipulation and seeding on total herbaceous yield (kg/ha) for 4 years after treatment.**

	Mechanical treatments							
Seeding treatment	R.P.[1]	F.E.	C	Mean	R.P.	F.E.	C	Mean
		1973[2]				1974		
Buffelgrass	3518	5053	2165	3579a[3]	6839	7364	1548	5250a
Native mixture	4235	2446	1481	2721b	5390	4478	1740	3869b
Nonseeded	3106	2222	1754	2361b	4988	3963	2185	3712b
Mean	3620a	3240a	1800b		5739a	5268a	1824b	
		1975				1976		
Buffelgrass	8480	5532	1308	5107a	9261	7462	3384	6702a
Native mixture	5429	4122	1652	3734b	8595	5984	3397	5992a
Nonseeded	4503	3563	1578	3215c	7423	5277	3944	5548a
Mean	6137a	4406b	1513c		8426a	6241b	3575c	

[1] Mechanical treatments are rootplowing (R.P.), front-end stacking (F.E.), and undisturbed control (C.)
[2] Data are accumulations of 2 harvests/year.
[3] Values followed by the same letter are not significantly different within each year at the 0.05 probability level as determined by Duncan's multiple range test. Comparisons for manipulation and seeding are made horizontally and vertically, respectively.

woody species (Fig. 1); but 3 years later, after rootplowing and front-end stacking, woody plant density had decreased. Brush species were controlled more effectively with rootplowing than with front-end stacking, but forage production was increased by both mechanical treatments.

Total Herbaceous Production

Mechanical treatments, with and without grass seeding, significantly increased total forage yields (Table 2). Forage production from the root-plowing treatment was two, three, and fourfold greater than that of the control in 1973, 1974, and 1975, respectively. In 1976, production was higher for all three main treatments, which was attributed to the high rainfall received during the growing season. Rainfall greater than 2.5 cm was received every month from March to December. Buffelgrass was the main contributor to the high forage production for the control treatment in 1976. By 1976, buffelgrass had invaded all unseeded plots of the control treatment as well as those of the rootplowed and front-end stacked treatments. Mean yields for rootplowing and front-end stacking treatments did not differ significantly ($P<0.05$) from each other in 1973 or 1974, but both treatments had significantly higher forage production than did the control. In 1975 and 1976, forage yields from the rootplowed treatment were significantly higher than that from either the front-end stacking treatment or the control. However, yields from front-end stacking treatment were significantly higher than that for the control. Mechanical treatments interacted significantly ($P<0.05$) with grass seeding treatments in 1975.

When we compared seeding treatments, buffelgrass seeded plots produced significantly more forage than did the native mixture treatment and the nonseeded treatments for the first 3 years. In 1973, 1974, and 1976, herbage yields from the native mixture seedings and nonseeded treatments were not significantly different. In 1975, all three seeding treatments different significantly from each other with buffelgrass the highest yielder, followed by the native mixture, and then the nonseeded treatment.

The application of N significantly ($P<0.05$) increased total forage production only during the season after application (1974). Forage production was increased 20 and 12% over that of the control, respectively, for rootplowed and front-end stacked treatments (data not shown). There were significant interactions ($P<0.05$) between fertilizer and mechanical treatments. The interaction indicated better fertilizer response to rootplowing seeded to buffelgrass than for any of the other treatments.

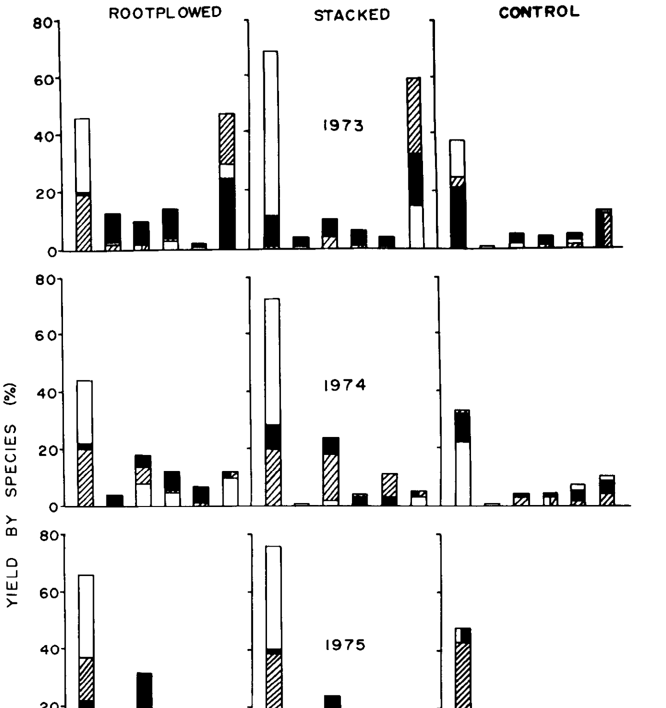

Fig. 2. Herbaceous forage yields by species from 1973 to 1976 after rootplowing, front-end stacking, and no treatment and seeded to buffelgrass, a mixture of five native grasses, and nonseeded. Species were buffelgrass (A), plains bristlegrass (B), four-flower trichloris (C), Arizona cottontop (D), pink pappusgrass (E), and total forbs (F). Each bar represents percent of the forage produced by each species on each of the three seeding treatments.

Forage Production by Species

The contributions of selected species to total herbaceous production under the mechanical treatments and the undisturbed control are shown in Figure 2. Buffelgrass was the most important single species contributing to forage yields regardless of treatment. Buffelgrass spread outside the seeded areas; moreover, the percent of buffelgrass production progressively increased from 1973 to 1976 on all treatments. The remaining herbage on the buffelgrass plots was primarily from nonseeded grasses and forb species.

In the mixture treatment, three seeded native species (pink pappus, four-flower trichloris, and Arizona cottontop) combined accounted for better than 20% of total yield all 4 years. The rest of the forage in this seeding treatment was produced by buffelgrass, voluntary nonseeded grasses, and forbs.

Major grass species on the nonseeded plots contributing to total herbage production included hooded windmill, Wright's threeawn, red grama, sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray), Texas bristlegrass, and false witchgrass (*Leptoloma cognatum* (Schult.) Chase). However, these species accounted for less than 40% of the total forage each year. The remaining herbage on this treatment was produced mostly by buffelgrass, four-flower trichloris, and forbs.

Forb contribution to total production was high the first year for both mechanical treatments, but decreased with time the last 3 years. Major forb species contributing to herbaceous yield included rose palafoxia, western ragweed, ragweed parthenium, bristleleaf dogweed (*Dypsodia tenuiloba* (D.C.) Robinson), and espanta vaqueros (*Tidestromia lanuginosa* (Nutt.) Standl.).

Infiltration Relationships

During infiltration tests, the soil was uniformly dry. At the initial test (August 1972), the 0- to 90-cm soil depth moisture content averaged 6.3%. At the second test (January 1975), the 0- to 90-cm soil depth moisture content averaged 7.6%.

Initial infiltration rates for soil subjected to rootplowing and front-end stacking were significantly higher than that for the control (Fig. 3). However, 30 months later, there were no significant ($P<0.05$) differences between treatments. During the first 5 minutes of the initial test, the infiltration was 55.5, 31.9, and 17.0 cm/hr for rootplowing, front-end stacking, and control treatments. This accounted for about 35% of the total water infiltrated during the first 1-hr test for all treatments. Rootplowed plots had the fastest infiltration rate during the first 100 minutes, but after that, front-end stacking plots had the fastest rate. For all time intervals up to 120 minutes, rootplowing and front-end stacking treatment values were 2.5 and 1.7 times greater than those for the control, respectively.

Thirty months after the mechanical treatments were applied, the infiltration rate for the first 5-minute interval was 18.8 cm/hr for both mechanical treatments and 17.0 cm/hr for the control, which accounted for 51% of the total water infiltrated the first hour.

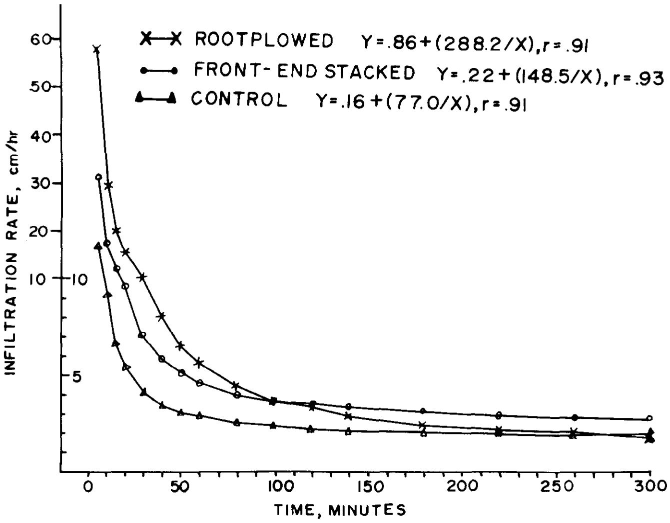

Fig. 3. *Comparison of water infiltration rates for two mechanical manipulation treatments and a control (August 1972). Data points are plotted at the mid-points of the time interval of measurement. Curve equation function and the regression value* (r) *are stated after each treatment.*

Water Relationships

Water use efficiency in grassland ecosystems is difficult to measure and interpret due to evaporation and transpiration losses, rainfall distribution patterns, varying amounts of ground cover, runoff, and soil disturbances.

Soil moisture data from March to December 1973 showed that initial soil moisture measurements were similar for all three treatments (Fig. 4). However, after June, soil moisture after rootplowing and front-end stacking was consistently higher than that for the control. Following high intensity rainfall (for example 16.5 cm in June and 22.2 cm in September), rootplowing and front-end stacking accumulated more soil moisture than did the control. Only in August, after only 0.50 cm of rainfall in July, was soil moisture depleted to about the same level on all treatments.

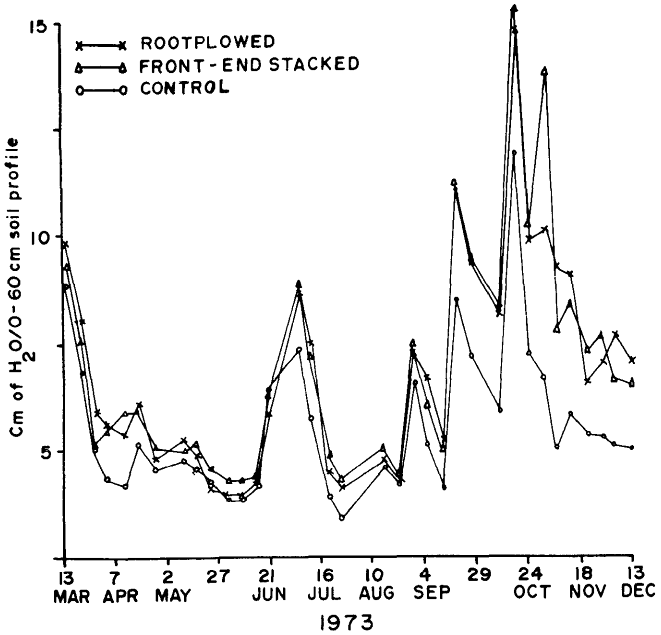

Fig. 4. *Soil moisture in 0- to 60-cm soil profile as measured weekly for three treatments. (Mar. to Dec., 1973).*

We compared soil moisture depletion for a 21-day period of no rainfall (July 5 to 26). On July 5, soil moisture at the 0- to 60-cm depth was 8.8, 9.0, and 7.5 cm of water for rootplowing, front-end stacking, and the control treatments, respectively. On July 26, soil moisture was 4.1, 4.4, and 3.5 cm for the three treatments, respectively.

When we measured soil moisture at the 0- to 90-cm depth, soil moisture after rootplowing and front-end stacking treatments was depleted by 0.33 cm/day as compared with 0.23 cm/day for the control. However, after 21 days, these two treatments still had more soil moisture for forage production than did the control, which reflected their higher infiltration capacity.

Discussion

Moisture data from this study helped to determine whether production increases are caused by more moisture in soil profile after brush removal and plowing (rootplowing) or more available moisture due to no plowing but less plant competition after woody plant removal (front-end stacking). It was apparent from the water infiltration and moisture use relationships that both mechanical treatments increased total forage production as compared with the control treatment. The large increase in production reflected the higher water infiltration rates and reduction in competition from woody plants after mechanical treatments. As a result, more soil moisture was available for plant growth of desired species. The increased grass herbage production during the 4-year study (seeded vs unseeded) was associated with the response of buffelgrass to above-average rainfall.

Buffelgrass herbage production in 1976 constituted about 44 and 51% of the total grass production on both mechanical and control treatments, respectively. Even though buffelgrass contributed a higher percent of forage on the control plots, total production was less due to lower plant density. However, invasions of buffelgrass plants on all treatments indicated this species' fast response to rainfall and its competitive ability with other perennial grass plants. The contribution to total yield by three native seeded species (pink pappus, plains bristlegrass, and Arizona cottontop) was generally highest the first 2 years following treatment and declined as time passed. Plains bristlegrass completely disappeared in 4 years, probably from selective heavy grazing. Four-flower trichloris, a seeded native species, increased with time for both manipulation treatments, but grazing animals did not utilize this species as much as they did other species. It was observed that the order of utilization by cattle was buffelgrass > plains bristlegrass > cottontop and pink pappus > four-flower trichloris.

The percent herbage contributed by voluntary native nonseeded grass species was consistent for mechanical manipulation treatments over time. Seeding and mechanical brush manipulation did not result in a significant change in herbage contributed by the volunteer nonseeded native species; however, a shift in some species did occur.

Percent herbage contributed by volunteer nonseeded grass species in the undisturbed control decreased from 1973 to 1976. The decrease in these species was attributed to the ability of buffelgrass to successfully compete with native grasses.

Herbage constituted by forbs was high the first year for both mechanical manipulation treatments, but by the fourth year it was down to 3%. The control treatment averaged about 10% forb herbage production and was generally consistent over time. The invasion of forbs as occurs in secondary succession following mechanical treatment poses a problem the first year; however, with time, forb densities decrease.

The change in grass composition from native species to buffelgrass will occur when buffelgrass is seeded. Observations from this study indicated that buffelgrass is more preferred by cattle than native grasses and is grazed more readily. Moreover, its fast growth characteristics and rapid recovery following rainfall promotes its ability to predominate or invade. Buffelgrass should not be seeded where a diversity that includes native perennial grasses is desired.

Herbage production on the rangelands of the Rio Grande Plain can be increased by fertilizer application. In this study, 45 kg/ha N, applied in the fall significantly ($P<0.05$) increased herbage production following both mechanical manipulations as compared with the control. However, the increase was only for the season following application, and no effect was evident during the second season. Perhaps at higher rates of application, residual responses could be obtained, but this would depend on seasonal rainfall after application. Another alternative would be to reapply a smaller amount each year rather than to try to carry over residual effects.

Summary and Conclusions

Vegetation of much of south Texas rangelands has changed since domestic livestock were introduced some 100 or more years ago. Generally, the change has been characterized by a reduction in perennial grasses and an increase in woody plants and cacti.

Mechanical manipulation of brush followed by grass seeding decreased or retarded brush growth and increased forage production threefold to fourfold. However, the major portion of forage increase was attributed to an introduced perennial grass, buffelgrass. The success of buffelgrass seeding can be enhanced greatly by rootplowing to increase water infiltration. New seedings must be protected from domestic livestock grazing for at least one growing season, and longer periods are desirable.

Application of 45 kg/ha N increased both annual and perennial grass herbage production in the mechanical treatments, but showed no effect in production in the undisturbed control. However, the increase lasted only one season. The cost/benefit analysis for using small amounts of fertilizer annually to increase the rate of range improvement and to improve distribution of use needs to be evaluated.

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