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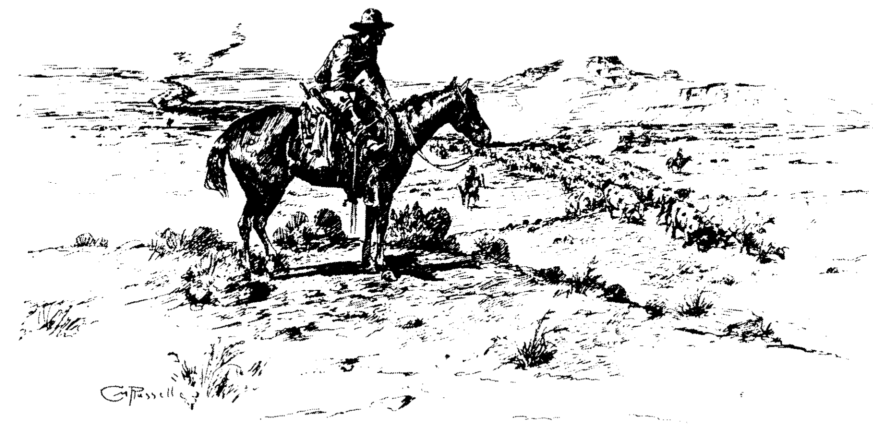

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TECHNICAL NOTES

Ages of Big Sagebrush Following Brush Control

JAMES W. BARTOLOME and HAROLD F. HEADY

Highlight: Six stands of big sagebrush, which had been plowed or sprayed earlier to remove brush and enhance understory vegetation, were sampled in southeastern Oregon to determine age structure of the shrubs and to evaluate rates of reinvasion. Five of the six stands contained big sagebrush older than the treatment. In three project areas plants established the first year following treatment formed the largest age class, 12 to 24% of the stand, indicating that reinvasion begins immediately after treatment. Most reestablishment occurred in the first several years after treatment for all locations. Establishment occurred either from seeds present in the soil at the time of treatment or from seeds produced as the plants became established and seed bearing. Treated sagebrush/grass ranges should remain highly productive under proper grazing use despite reinvasion of big sagebrush.

This report describes the age structure of big sagebrush (*Artemisia tridentata*) in areas of brush control and seeding of crested wheatgrass (*Agropyron cristatum* and *A. desertorum*). Age structure of stands has application to the status of vegetation modification, with particular relevance to the projected lifespan of the treatment, effectiveness of the treatment, and plans for future management.

The location of this study, the Vale District of the Bureau of Land Management (BLM) in southeastern Oregon, was the subject of a large scale rangeland rehabilitation program extensively evaluated elsewhere (Heady and Bartolome 1977). The BLM spent about 10 million dollars on the Vale District to reduce stands of big sagebrush, either to permit seeding of exotic forage species or to enhance the growth of native understory plants, mainly bluebunch wheatgrass (*Agropyron spicatum*). The primary goals were to halt soil erosion and to stabilize the local livestock industry through increased grazing capacity.

Eighty-eight percent of the Vale District is dominated by big sagebrush, and vegetation of the remainder has a strong shrub component. This vast area of sagebrush/grass is characterized by complex, intergrading mixtures of several dominant shrub and grass species depending upon prior treatment and varying microsite. Excellent condition range may contain up to 25% sagebrush and 75% grass cover. The mix of bunchgrasses and sagebrush at the start of the Vale Program had been changed toward high brush density, often greater than 50% cover, and few palatable bunchgrasses as a result of a century of exploitive grazing. In some locations a perennial grass understory was almost absent, with annuals or bare soil between the shrubs.

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The assistance of the Bureau of Land Management, Oregon State and Vale District Offices, and the U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station, is gratefully acknowledged.
Ron Wakimoto, Lin Yeilding, and Jesse Theuri contributed to the study.
Manuscript received September 3, 1977.

Literature

Understanding of the effects of range improvement primarily depends upon quantification of the ecological processes involved in productivity. Much published work has reported on aspects of vegetation change, ecosystem processes, and management of sagebrush-grass range. Papers cited emphasize big sagebrush changes following control.

Sagebrush eventually reinvades where it has been controlled in most instances. The rate of invasion is related to initial success of shrub control (Weldon et al. 1958), initial condition of the range (Hedrick et al. 1966), and success of seeding (Robertson et al. 1966; Frischknecht and Bleak 1957). Yet reestablishment is often highly localized (Hironaka and Tisdale 1963) and concentrated in certain, perhaps wet, years (Frischknecht and Harris 1968). Heavy grazing speeds the rate of reinvasion (Johnson 1969); yet big sagebrush reinvades in some years even without grazing (Frischknecht and Harris 1968).

Different subspecies of *Artemesia tridentata* may behave differently. The unpalatable subspecies *A. tridentata tridentata* may be the most aggressive (McDonough and Harniss 1975). Differences between subspecies *Artemesia tridentata vaseyana* and *A. tridentata tridentata* may have led to several conflicting results in rate of reinvasion. Additional confusion on reinvasion rates stems from the apparent lack of correlation between size and age in immature *Artemesia tridentata tridentata* (Beetle 1960; Daubenmire 1975). Some authors used size classes as estimates for age of plants. The long delay before reinvasion reported by Harniss and Murray (1973) could also lead to inaccurate conclusions concerning reinvasion of brush.

Economists have generally regarded chemical control of sagebrush as having a finite life span, usually less than 20 years (e.g., Kearl and Branham 1967). They project a finite life span based on the comparison of adjacent treated and untreated areas, where the difference disappears in between 10 to 20 years. This comparison would be clouded by additional improvement of both treated and untreated ranges. Kearl (1965) found that more than 50% of respondents to a survey of individuals using herbicides to control big sagebrush between 1952 and 1964 did not plan ever to respray. Seedings following mechanical control are also generally regarded as finite in life span, usually 20 years (e.g., Caton and Beringer 1960), perhaps with even less justification than for brush control alone. One would hope that proper management of rehabilitated big sagebrush-grass would not result in deteriorated stands after 20 years.

The economics of large scale brush control and seeding operations have yet to be adequately developed. On the Vale District the initial efforts by Stevens and Godfrey (1976) and Nielson, et al. (1966) have not adequately addressed problems associated with the quantification of interactive effects of a wide spectrum of range-improvement practices. Benefits are not confined to treated areas alone. Adjacent untreated range improved at least as spectacularly as the treated range on the Vale District (Heady and Bartolome 1977), a result which must be included as a benefit. Economic evaluation therefore needs to consider the district or ranch as a whole.

Methods

Methods of vegetation sampling used in this study provide information on the life expectance of range improvement treatments instigated by the Vale Program.

In June 1976, 50 sagebrush plants were collected in each of six project areas to determine age through ring counts, density on the ground, and size of plants. All big sagebrush plants within a randomly located 1 m wide belt were measured for crown diameter and height and cut at ground level for ring counts to estimate age. The sampling ended when 50 plants had been collected. Density then was determined from the length of the transect. Ferguson (1964) discusses ring-dating in detail for big sagebrush. Although rotten centers and incomplete rings reduced the accuracy of age determination, the number of annual rings in any stem younger than approximately 20 years gave a reasonably clear estimate of the age of the plant. Estimates of actual age were not possible with 29 brush plants, or about 10% of the samples, due to missing centers.

Six project areas within the Vale District constituted the study areas. Five were plowed prior to seeding (Table 1), while one was sprayed with 2,4-D to kill brush. All areas are currently grazed by cattle. The oldest treatment is 24 years old, the most recent 9 years. No obvious differences relating only to age of treatment were noted.

Results and Discussion

An apparent total initial control of brush resulted in the Ten-Mile seeding project because it was the only project area which did not contain sagebrush plants older than the treatment (Fig. 1). The most abundant age class represented those plants which established in the first year following treatment. However, sagebrush plants continued to establish during later years following treatment. No plants younger than 4 years old were found. An interesting aspect of the age structure of the big sagebrush population in this project area is an apparent second period of establishment five years following the initial period of establishment. This second peak could be due to seedlings established as the first group of plants became old enough to produce seed or an exceedingly favorable year for establishment. The structure of the stand suggests an effective control, completely eliminating the brush, but a rapid and continued reinvasion in the years following treatment.

The four other plowed and seeded areas (Antelope, Brickey Springs, Big Ridge, and Rock Creek) displayed similar patterns of population structure (Fig. 1). A few plants apparently survived the initial plowing. Reestablishment of the brush then proceeded rapidly in the years following treatment. The first year following treatment was the largest age class in the Big Ridge and Antelope project areas. Establishments of sagebrush rapidly declined in successive years following treatment. Establishment was more continuous with a later peak in the Rock Creek and Brickey Springs projects.

Brush control was very poor in the Basque spray and seed project. Many of the shrubs were more than 25 years old (Fig. 1). However, the pattern of reinvasion following treatment is similar to the more effective plow treatments. Density of sagebrush in the Basque spray was less than for the more effectively controlled area of Rock Creek, where few of the shrubs survived treatment (Table 1). Reinvasion of sagebrush is apparently not significantly related to the degree of brush kill for these areas.

A common assertion is that big sagebrush invades rapidly following land treatment and that most seedlings become established at that time. In part, the results of the age-class survey substantiate that claim. On three of the treated areas the most numerous age class occurred the year following treatment. However, all treated areas showed evidence of continued establishment for several years following treatment, except that the Antelope and Brickey Springs seedings had no plants younger than 6 years (Fig. 1).

Only the Ten-Mile seedings displayed complete control of big sagebrush by the initial treatment; in all other projects sampled, ample big sagebrush plants remained after treatment to allow reinvasion from seed produced. Invasion was by establishment of seedlings immediately after treatment from seed on the site and from seed produced later. No evidence was found that particular years were more favorable for sagebrush establishment than others. Individual areas showed groups or cohorts of seedlings but they were of different ages. From 1970 onward few big sagebrush plants became established.

Size and age of plant were poorly correlated. Although correlation coefficients for age (number of annual rings) and size (height times square of diameter) of plant were statistically significant for five of the six areas, coefficients were low and of little use for predicting age (Table 1). The Big Ridge seeding showed a correlation of 0.130 or no relation at all between size and age. Interestingly, the Big Ridge seeding consisted primarily of the subspecies *Artemesia tridentata tridentata* Nutt.

Table 1. Age in years and density of big sagebrush on six treated areas in 1976.

Project name	Brush control method	Primary big sagebrush subspecies[1]	Age of treatment (years)	Age (years) of big sagebrush: Mean	Median	Minimum	Maximum	Density of big sagebrush (plants/m²)	Correlation between size and age "r" [2]
Ten-Mile Seeding	plow	wyomingensis	24	17.7	19	5	24	0.29	0.348*
Brickey Springs Seeding	plow	wyomingensis	15	12.6	13	6	21	0.20	0.448**
Rock Creek Seeding	plow	wyomingensis	15	12.2	12	5	26+	0.53	0.427**
Big Ridge Seeding	plow	tridentata	10	9.3	10	1	18	0.20	0.130
Antelope Seeding	plow	wyomingensis	10	11.2	10	7	23	0.27	0.457**
Basque Brush Control	spray	wyomingensis	9	15.4	11	3	38+	0.45	0.486**

[1] *wyomingensis* indicates primary big sagebrush subspecies present was *Artemesia tridentata* subsp. *wyomingensis* Beetle. tridentata indicates primary subspecies present was *Artemesia tridentata* subsp. *tridentata* Nutt.

[2] * and ** denote significant correlation between size and age at the .05 and .01 levels, respectively.

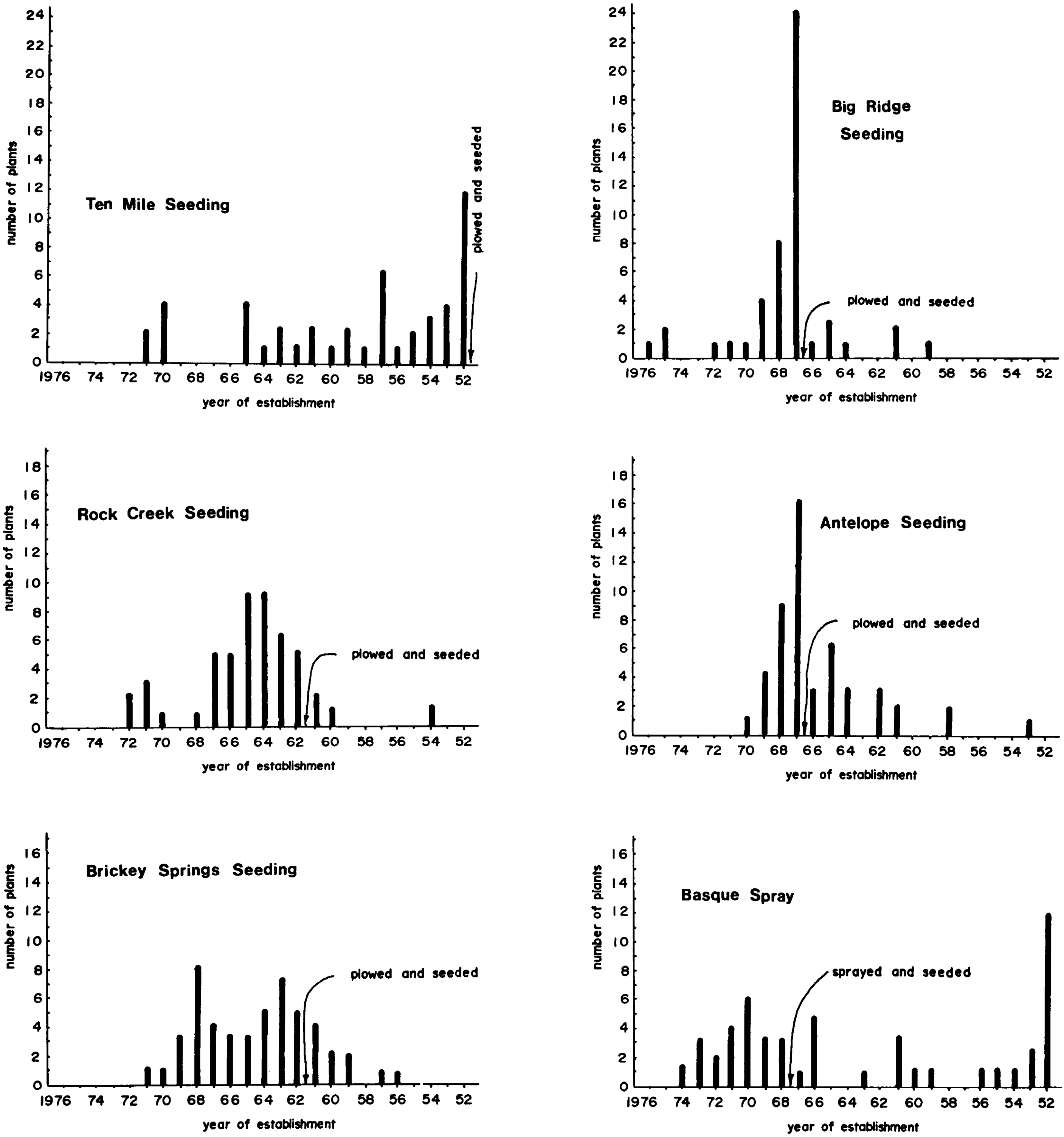

Fig. 1. *Apparent year of establishment of big sagebrush plants within six treated areas as determined through ring counts. Bars represent the number of plants established in each year out of 50 sampled.*

while the others were primarily *A. tridentata wyomingensis* Beetle, as classified using the criteria of Winward and Tisdale (1977). The practice of making inferences about age class distribution of sagebrush stands based on size classes is highly inaccurate and in fact may lead to erroneous conclusions. Apparent seedlings less than 1 dm (5 in) tall may be more than 10 years old.

Benefits of treatment during the Vale Program should last indefinitely under the present proper management. This premise is based on several facts and assumptions. Stands of grass appear to have deteriorated in the first few years following treatment, but most of the apparent reinvasion of big sagebrush is actually the recovery of unkilled plants and the growth of seedlings established in the first few years following treatment. Seedlings established later than the first year following treatment generally remained small, and many did not reach maturity. Old brush control projects did not show more sagebrush reinvasion than recent projects, and on several sites continued reinvasion of big sagebrush appeared to be completely halted after the early reestablishment following treatment and before the thickening of the grass stand. Areas with nearly complete big sagebrush kills showed invasion with densities not ultimately different from less effectively controlled areas.

An often misconstrued aspect of vegetation change in sagebrush/grass range is that since depleted sagebrush/grass ranges contain mostly sagebrush, perhaps with a large quantity of cheatgrass (*Bromus tectorum*), sagebrush reinvasion will bring deterioration of the perennial grass cover. We reject this negative correlation between sagebrush density and grass productivity on well-managed ranges. Sagebrush/grass ranges may contain a high proportion of big sagebrush before grass production will be significantly decreased. The key to proper management is maintenance of a balance between vigorous stands of perennial grasses and big sagebrush. Judiciously used brush control practices, seeding, and proper grazing can maintain this balance.

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Patterns of Natural Revegetation In Arid Southeastern Utah

RICHARD A. JAYNES AND K.T. HARPER

Highlight: Current and pending legislation will require that lands disturbed by mining activities be revegetated. Since few adapted species are now available for reclamation of such lands in the arid zone, this study was initiated to identify native species that are successful colonizers of disturbed sites. The native vegetation of bladed roadways in the Kane County, Utah, was sampled to identify natural colonizer species. Sixteen successful colonizers have been identified and studied to determine (1) their relative colonizing efficiency, and (2) their individual responses to elevational, soil textural, and other environmental gradients. The species fall into two natural groups: one group is well adapted to lower benchlands with sandy clay loam soils and the other is adapted to upper benchlands with sandy loam soils. Some of the species that appear to be most successful in initially revegetating disturbed areas include: (1) upper benchlands—Indian ricegrass, galleta grass, sand aster, pepperweed, broom snakeweed, small-leaf scarlet globemallow, and blue locoweed; (2) lower benchlands—shadscale, desert molly, cut-leaf globemallow, and pink locoweed.

Large deposits of low sulfur coal and oil shale occur in the arid zones of the Colorado Plateau. National needs will almost certainly require the use of all energy resources that can be mined economically. Resultant energy development operations will disrupt the natural vegetation over extensive areas of arid land. Since current and pending legislation requires that plant cover be reestablished on such lands, there is an urgent need for workable revegetation techniques for arid environments. Without some kind of stabilization treatment, mine spoils, roadsides, drill pads, and construction sites associated with energy developments will contribute significant amounts of particulate matter to the air and sediments and dissolved chemicals to surface waters in the region. The cheapest and most nearly permanent method of stabilization is likely to be revegetation with well-adapted plants. Reclamation with appropriate plant species could serve not only to restore but also to improve range productivity for wild and domestic animal life.

Although much successful revegetation work has been accomplished in portions of the West that receive over 30 cm of precipitation annually (Plummer et al. 1968), plant scientists have had little success in establishing permanent ground cover on disturbed sites where annual precipitation falls below 25 cm (Bleak et al. 1965). The current inability to establish quickly plant covers in arid zones is related to a lack of information on adapted species and to the unpredictability of natural precipitation.

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This study was designed to sift the native flora of the benchlands of the Kaiparowits Basin, a potentially important coal field, for native species capable of naturally recolonizing disturbed sites. We also provide some information concerning ecological situations where such species might best be used.

Description of Study Area

Vegetation and associated soils were sampled on upper and lower benchlands northeast of Glen Canyon City, Utah. Soils of the upper benchland sites (ca. 1,550 m) are predominantly sandy loams derived from the Straight Cliffs sandstone formation with some localized Mancos shale influence. Soils on lower benchland sites (ca. 1,330 m) range from clay soils from tropic shale to sandy clay loams derived from Straight Cliffs or Dakota sandstone.

The study area is characterized by elements of both cold and warm desert vegetation adapted to less than 25 cm of mean annual precipitation. Moisture is received as winter snow, spring rain, and localized summer thunderstorms. The monthly precipitation averages form a bimodal pattern as a result of winter storms from the west and the intrusion of summer air masses from the Gulf of Mexico. Years of below-average precipitation are more frequent than above-average years. Wet winters are not always followed by wet summers, nor are dry winters necessarily followed by dry summers. Native plant species have adapted to these extreme moisture fluctuations in various ways. Annuals are abundant in the study area and flourish in wet years, but exist as seeds during drought years.

The vegetaion of the Kaiparowits Basin provides winter forage for livestock, and both habitat and forage for black tailed jackrabbits, various smaller rodents, and a variety of birds. Though sparse, the plant cover also enhances soil stability.

Methods

A total of 21 study sites was selected along roadways in shadscale-grass, blackbrush, sagebrush, and grassland-shrub communities. Roads were selected that had been graded in such a way as to remove the top 2-3 dm of soil and place it in a windrow at road edge (Fig. 1). The time since disturbance was at least 3 years, and none of the roads had received artificial surfacing materials such as petroleum stabilizers or gravel. On older roads, it proved impossible to determine accurately the length of time since disturbance, but it was obvious that each site sampled supported pioneer vegetation in the roadway and along the windrow of mixed surface soil. Three stands were selected at each site at the following locations: (1) road center where subsoil had been exposed and plants could exist without being crushed by vehicular traffic, (2) adjacent roadside berm (consisting of a mixture of subsoil and topsoil), and (3) a strip of undisturbed vegetation 10 m away from and parallel to the road. The three stands at each site will hereafter be referred to as subsoil, mixed soil, and undisturbed. Each stand consisted of a transect 120 m in length and centered on the area of

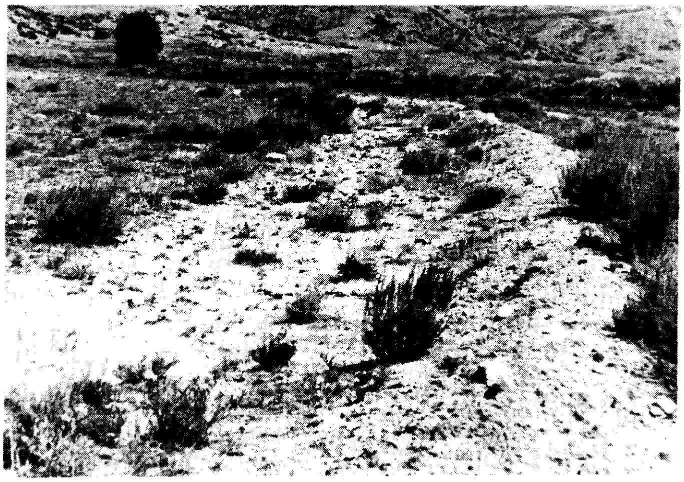

Fig. 1. *Roadways had all been made by a grader or bulldozer passing over the site to clear off brush and smooth off surface irregularities. Plant debris and surface soils were windrowed into a berm at roadedge. There had been no attempt to form gutters or elevate roadbeds. Plant life persisted in the center of all roads sampled.*

interest (e.g., the berm). Twenty-five quadrats (0.25 x 1.0 m) were distributed along the transect at 5-meter intervals. Transects were selected for maximal topographic and edaphic homogeneity. The undisturbed stand adjacent to the roadway was viewed as being the principal seed source for colonizing species.

Vegetational data were collected in early June 1975. A checklist of all plant species occuring along each transect was made. At each quadrat, density of all perennial species rooted therein was noted and living, dead, and rock ($\geq$1 cm^2) cover was estimated by cover classes (Daubenmire 1968). The plant nomenclature follows Welsh and Moore (1973). A list of the most prolific colonizer species was made by selecting the species most frequently encountered on disturbed areas. The relative abundance of species was also used to help arrange the list of important colonizers.

At each study area, a composite soil sample was drawn from the surface 1.5 dm. It consisted of equal quantities of soil from each transect. Soils were analyzed for texture using the hydrometer method (Foth et al. 1971).

The average frequency of each selected species was calculated for all disturbed (i.e., subsoil or mixed soil) and all undisturbed transects. Transects within each soil class were then arranged in order of decreasing frequency of the species in question. Average elevation and average % sand for transects of the top ⅓ of the frequency gradient of each species were then computed and graphed.

Colonizing success of each species relative to its seed source was determined by dividing the density of each species on a disturbed area by the density of the same species in the adjacent undisturbed area and multiplying the quotient by 100. Values exceeding 100 indicate that a species is present on disturbed areas in greater abundance than in adjacent seed source areas. Thus, this index serves as an indicator of colonization efficiency.

Results and Discussion

Information concerning general characteristics of the different vegetative types is given in Table 1. A total of 54 perennial species was observed on the 21 study areas. Sixteen of the most abundant colonizer species were selected for further study. The list includes 6 shrubs, 7 perennial forbs, and 3 grasses. The scientific and common names of those species and the general areas of their occurrence in the region are reported in Table 2. The usual means by which each species propagates itself on the disturbed sites is also noted.

Comparative response of the 16 colonizer species along elevational and soil textural gradients is shown in Figure 2. The sandy loam soils of higher elevations are most readily colonized by Indian ricegrass, galleta grass, Fendler's three-awn, broom snakeweed, big sagebrush, Mormon tea, sand aster, Hymenopappus, pepperweed, blue locoweed, and small-leaf scarlet globemallow. The clay loam soils of lower elevations are mainly colonized by shadscale, desert molly, budsage, pink locoweed, and cut-leaf scarlet globemallow. The rank-order of species along the elevational and soil textured gradients is highly correlated at the .01 level (Snedecor and Cochran 1967), indicating that species that prefer low elevations also do best on finer textured soils in our study area.

The arithmetical means reported in Figure 1 may be somewhat misleading, since variance around the mean is not considered. The coefficient of variation ($C.V.$ = standard deviation/arithmetic mean × 100 was examined for each species. Coefficient of variation values for four species (blue locoweed, cut-leaf globemallow, galleta grass, and Indian ricegrass) are somewhat larger ($C.V.$ = 5-11 for elevation and $C.V.$ = 35-39 for soil sand), than for the other species ($C.V.$ = 1-4 for elevation and $C.V.$ = 9-23 for soil sand. Such results

Table 1. General environmental and vegetational characteristics associated with five vegetation units recognized in this study. Vegetational data are from the undisturbed transects at each study site.

Vegetation type	Average elevation (m)	Soil parent material	Soil textural class	Number of study areas	Benchland designation	Average living Plant cover ± *SD*
Shadscale-grass	1,310	Alluvium from Straight Cliffs sandstone and Tropic shale	Sandy clay loam	6	Lower	18 ± 5
Grassland-shrub	1,520	Straight Cliffs sandstone residuum with some localized Mancos shale	Sandy loam	5	Upper	26 ± 2
Spiny hopsage	1,586	Straight Cliffs sandstone	Sandy loam	4	Upper	34 ± 6
Blackbrush	1,582	Straight Cliffs sandstone	Sandy loam	4	Upper	20 ± 6
Sagebrush	1,650	Straight Cliffs sandstone	Sandy loam	2	Upper	27 ± 2

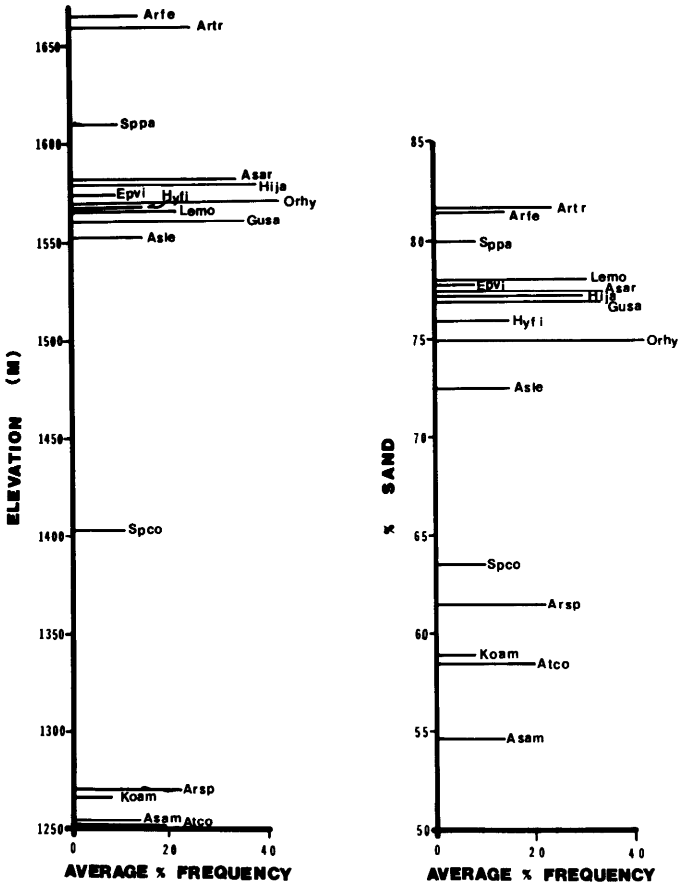

Fig. 2. *Environmental conditions associated with maximal development for important colonizer species along roadedges in the Kaiparowits Basin. Only stands from the top third of the density gradient for each species were considered in constructing this figure. Length of the horizontal line for each species indicates the average frequency of that species in quadrats placed in subsoil and mixed soil stands at the sites considered. Species abbreviations are shown in Table 2.*

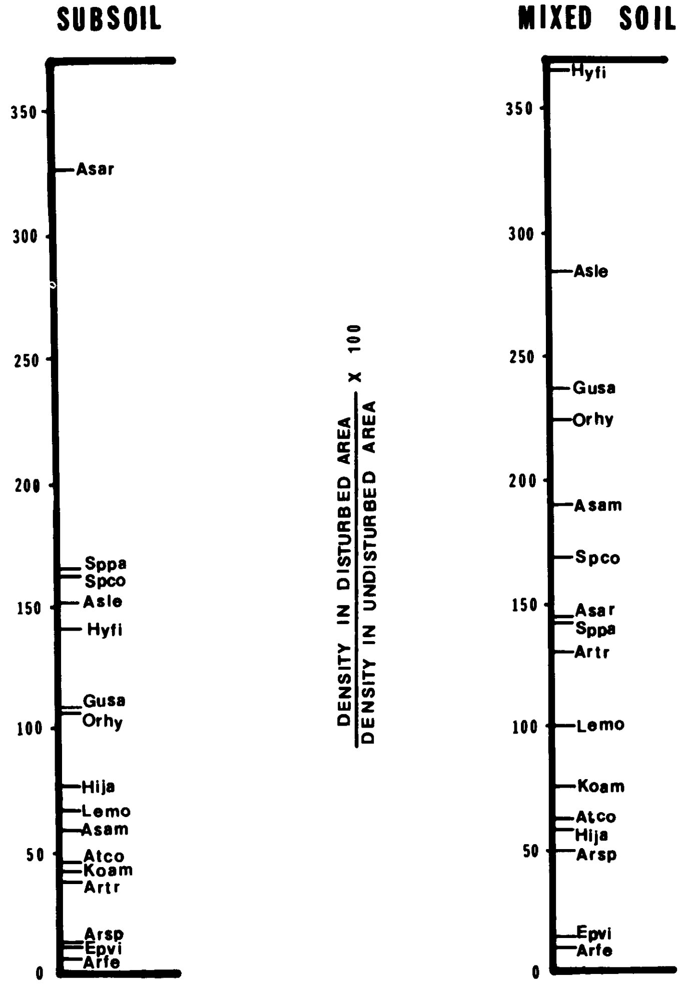

Fig. 3. *Relative success of the species as colonizers. Species unable to persist in disturbed sites would have a value of zero; a value of 100 indicates that the species is as abundant in the disturbed as in the undisturbed area. The horizontal scale has no meaning. Abbreviations are as in Table 2. The vertical axis is identical for subsoil and mixed soil.*

suggest that these four species are less restricted than the others in respect to edaphic and elevational requirements. Snakeweed occurs over a broad range of elevations; but it grows preferentially on sandy loams. Shadscale tolerates a rather broad range of soil texture, but it a vigorous colonizer only at lower elevations.

It should be noted that colonizing species of lower benchlands include few species that are capable of sprouting from roots under natural conditions (Table 2). Upper benchland areas appear to be more favorable for vegetative propagation, since several species there (especially forbs) reproduce vegetatively following disturbance.

The performance of the various species on disturbed and undisturbed areas can be used to compute a useful measure of the relative ability of each to colonize newly opened sites from a parental population of standardized size. The species are ranked according to colonization success on subsoil and mixed soil sites in Fig. 3. Broom snakeweed, Indian ricegrass, both scarlet globemallows, and both locoweed species appear to be among the more efficient colonizers of disturbed areas (i.e., they were found in greater abundance on the disturbed sites than in the adjacent source area.) Sand aster and *Hymenopapus* also do well on both kinds of disturbed sites. Part of the success of the latter two species may be due to their ability to reproduce vegetatively from plant parts buried so deeply that they escape destruction in the process of road construction. Again, it is apparent that the upper benchlands represent a more favorable environment for plant growth, since most of the highly efficient colonizers are found there.

Most of the species considered perform better on the mixed soil berm than the scraped roadbed (Fig. 2), but three species reach maximum density in the road itself (sand aster, small-leaf globemallow, and galleta grass). Performance of those species appears to be hampered by competition from associated species on less disturbed sites.

Stepwise multiple variable regression analyses of environmental factors controlling the performance of species selected as good colonizers have been performed. These analyses are based on data for 72 undisturbed sites from a study by Jaynes (1976) which was conducted in the same area utilized for this study. Environmental variables considered in the analyses include soil texture, salinity, pH, and stoniness, water infiltration rates, and microtopography (elevation, aspect and % slope). Frequency of species occurrence was used as the dependent variable. Results are reported in Table 3. Multivariate equations are helpful in predicting species response to selected variables, but they had limited value as predictors of relative colonizer success on denuded sites in this study. The rather low R^2-values would have been improved by increasing

Table 2. Important colonizing species on disturbed sites in the Kaiparowits Basin.

Scientific name	Common name	Symbol	Community of best development	Benchland of best development	Commonest means of propagation on disturbed sites
Shrubs					
Artemisia spinescens	Budsage	Arsp	Shadscale	Lower	seed
Artemisia tridentata	Big sagebrush	Artr	Sagebrush	Upper	seed
Artiplex confertifolia	Shadscale	Atco	Shadscale	Lower	seed
Ephedra viridis	Mormon tea	Epvi	Grassland-shrub and spiny hopsage	Upper	seed, root?
Gutierrezia sarothrae	Broom snakeweed	Gusa	Shadscale	Upper	seed, root?
Kochia americana	Desert molly	Koam	Shadscale	Lower	seed, some rhizome
Forbs					
Astragalus amphioxys	Pink locoweed	Asam	Shadscale	Lower	seed
Astragalus lentiginosus	Blue locoweed	Asle	Grassland-shrub and blackbrush	Upper	seed
Aster arenosus	Sand aster	Asar	Sagebrush	Upper	seed, rhizome
Hymenopappus filifolius	Hymenopappus	Hyfi	Grassland-shrub	Upper	seed, root?
Lepidium montanum	Pepperweed	Lemo	Blackbrush	Upper	seed
Sphaeralcea coccinia	Cut-leaf scarlet globemallow	Spco	Shadscale	Lower	seed
Sphaeralcea parvifolia	Small-leaf scarlet globemallow	Sppa	Grassland-shrub	Upper	seed, root?
Grasses					
Aristida fendleriana	Fendler's three-awn	Arfe	Grassland-shrub	Upper	seed
Hilaria jamesii	Galleta grass	Hija	Grassland-shrub and spiny hopsage	Both	seed, rhizome
Oryzopsis hymenoides	Indian ricegrass	Orhy	Grassland-shrub and spiny hopsage	Both	seed

the range of variation encountered in species success in the stands studied (e.g., including disturbed sites where species are colonizing). Nevertheless, the equations do provide useful information concerning the ecology of species which may have value in revegetation programs (Wikum and Wali 1974).

Some of the species found growing on disturbed sites in this study had apparently not become established by seed but had survived disturbance by sprouting from the crown or from rhizomes (e.g., both globemallow species, pepperweed, galleta grass, and Mormon tea). Since the ability of plants to persist on harsh sites is an important characteristic of good colonizing species, we have made no distinction between plants occurring

Table 3. Multivariate regression equations for colonizer species. The dependent variable in all cases was % frequency of each species.

	Number of study sites of occurrence	Regression equation* y = the percent frequency of each species in 0.25 m² quadrats	R^2	Significance
Shrubs				
Artemisia spinescens	21	y = 11.1-.07E + .01Sa + .61%S1 - .39SD - .41R + 3.18SP	.42	n.s.
Atriplex confertifolia	45	y = 53.6 - .07E - .79C + 10.90Ex + 10.17pH - .27IR + .0009 SA	.35	.025
Ephedra viridis	57	y = -45.2 - .38R + .04E - 4.50SP + .24S + .18IR - 3.77 Ex	.46	.005
Gutierrezia sarothrae	63	y = -151.5 + .50S + .08E - .24IR + .47SD + .63 R + 3.78SP	.48	.005
Kochia americana	15	y = 44.8 + 1.73C - 13.72 EX - .05E + .22IR	.81	.005
Forbs				
Aster arenosus	47	y = -50.1 -6.1Ex + 8.1pH - .10IR + .0850	.22	.05
Astragalus amphioxys	63	y = 63.1 - 6.18pH - .0008Sa + .06SD + 1.60 Ex - .008E	.16	n.s.
Astragalus lentiginosus	29	y = 105.5 - .04E - 5.4pH - .003Sa	.61	.005
Lepidium montanum	48	y = 158.8 + 11.73Ex - 23.63 pH + .05E - .01Sa - .36S - .11SD	.48	.005
Sphaeralcea coccinea	45	y = 15.8 - .06SD + .002SA - 1.12Ex - 1.20pH - .41SP	.38	.005
Sphaeralcea parvifolia	33	y = 122.9 - .53C - .38R - 12.41pH - .04Sa	.27	n.s.
Grasses				
Aristida fendleriana	30	y = 0.2 + .28SD - .007Sa - .12IR	.44	.005
Hilaria jamesii	70	y = 264.5 - 2.32C + 9.52SP - .89S - 1.66%S1 - .08E - .66R	.40	.005
Oryzopsis hymenoides	70	y = 86.8 + 6.47SP - .97%S1 - .23C + .16SD - 9.41pH	.19	.025

* Variables are arranged in the sequence of their entry into the stepwise regression.

Key to symbols used:

C = % Clay	SP = slope position (top = 1, middle = 2, bottom = 3)
S = % sand	SD = soil depth (cm)
%S1 = slope	EX = exposure (2.00 = Northeast, 0.00 = Southwest)
E = elevation (m)	Sa = soil salinity (ppm)
R = % soil rock	pH = soil pH (1:1 soil/water paste)
	IR = infiltration rate (cm/min)

on a disturbed site as a consequence of seedling establishment or resprouting. From our field observations, however, the majority of the species considered to be effective colonizers apparently had invaded by seed.

Some of the candidate species noted have undesirable forage properties (e.g., snakeweed and locoweed). Where vegetative cover is the main goal, unpalatability may become a secondary consideration. Along roadsides where grazing animals present traffic hazards, unpalatable plants may actually be desirable. Species such as sand dropseed (*Sporobolus cryptandrus*) and squirreltail (*Sitanion hystrix*) have been recommended for inclusion in seeding mixtures for sandy, arid sites (Plummer et al. 1955). Although these species were often present in undisturbed communities adjacent to our disturbed plots, they were not good colonizers for our roadways.

The existing flora of the Kaiparowits Basin is a valuable source of adapted species for land reclamation projects on the Colorado Plateau, but not necessarily the only group of plants that should be considered. Some introduced perennial and annual species may also play important roles in future reclamation projects.

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Effects of Cattle Grazing on Shore Vegetation Of Fluctuating Water Level Reservoirs

G.R. HOFFMAN AND L.D. STANLEY

Highlight: Shore vegetation around Lakes Oahe and Sakakawea, mainstem Missouri River reservoirs, is a mosaic of shifting plant populations that responds to a combination of limiting factors including water level fluctuations and cattle grazing. Shore vegetation is important as it provides some wildlife habitat and spawning habitat for certain fish species, reduces erosion, adds to the aesthetic value of the shore environment, and provides forage for cattle grazing. The present study was done in 1976 to document the effects of cattle grazing on shore vegetation at seven sites that were inundated for a prolonged period in 1975. Some of the dominant shore species were *Horedeum jubatum, Agropyron smithii, A. repens, Chenopodium album, Iva xanthifolia, Kochia scoparia* , *Melilotus ssp.*, *Polygonum achoreum, P. lapathifolium, Rumex crispus*,, and *Xanthium strumarium. Solanum rostratum* and *Grindelia squarrosa* along with several other species were favored by grazing. Floristically, ungrazed plots were more similar than grazed plots when pairs of sites were compared. Total plant coverages inside exclosures at three sites on Pierre Shale-derived soils ranged from 54% to 97% and biomass values ranged from 458 g.m^{-2} to 720 g.m^{-2}, while outside exclosures at the same sites total plant coverages ranged from 11% to 82% and biomass values were 19 g.m^{-2} to 259 g.m.$^{-2}$. At one site, on loess-derived substrate, total plant coverages inside and outside the exclosure were 116% and 77% respectively, and biomass values were 606 g.m^{-2} inside and 210 g.m^{-2} outside the exclosure. All three sites on Lake Sakakawea are on glacial till-derived substrates, and plant coverages ranged from 128% to 155% inside exclosures where biomass values were 478 g.m^{-2} to 1,766 g.m^{-2}. Outside the exclosures the total plant coverages were 24% to 144% and biomass values were 15 g.m^{-2} to 474 g.m^{-2}.

Shore vegetation develops between periods of high water; thus annual fluctuations in water levels, along with cattle grazing as limiting factors, keep shore vegetation in an early seral stage. Minimizing both water level fluctuations and cattle grazing for a given reservoir during a given year, preferably a 2-year period, would permit considerably more shore vegetational development. This regimen, if rotated among the six reservoirs, would over a period of years, benefit development of shore vegetation.

Cattle grazing is a major enterprise in the western North and South Dakotas. Along the Missouri River reservoirs in these states, cattle have ready access to both shore vegetation and water. While it has been recognized for many years that cattle grazing can decrease significantly the shore vegetation of ponds, lakes, and reservoirs (Gill and Bradshaw 1971; Kelting and Penfound 1950; Magadza 1970; Tiemeier 1951), the effect of cattle grazing on shore vegetation of the Missouri River reservoirs has not been studied previously.

Lakes Oahe and Sakakawea, mainstem Missouri River reservoirs (Fig. 1), have fluctuating water levels that peak during the summers and reach low during the winters. Water fluctuation patterns vary from year to year in each reservoir and are quite dissimilar between the two reservoirs. For the years 1969-1975, the average water level fluctuations were 3.58 m (11.7 ft) and 3.45 m (11.3 ft) in Lakes Oahe and Sakakawea, respectively. Based on lake basin morphometry data of 1968 (U.S. Army Corps of Engineers 1971, 1972) these water level fluctuations translate to shore areas of 20,658 ha (51,025 acres) and 19,422 ha (47,972 acres) for Lakes Oahe and Sakakawea, respectively. In 1975, when water reached record high levels in both reservoirs, 27,738 ha (68,513 acres) around Lake Oahe and 26,380 ha (65,159 acres) around Lake Sakakawea were inundated. Following high water, vegetation becomes established on the shores and survives until high water and/or cattle grazing

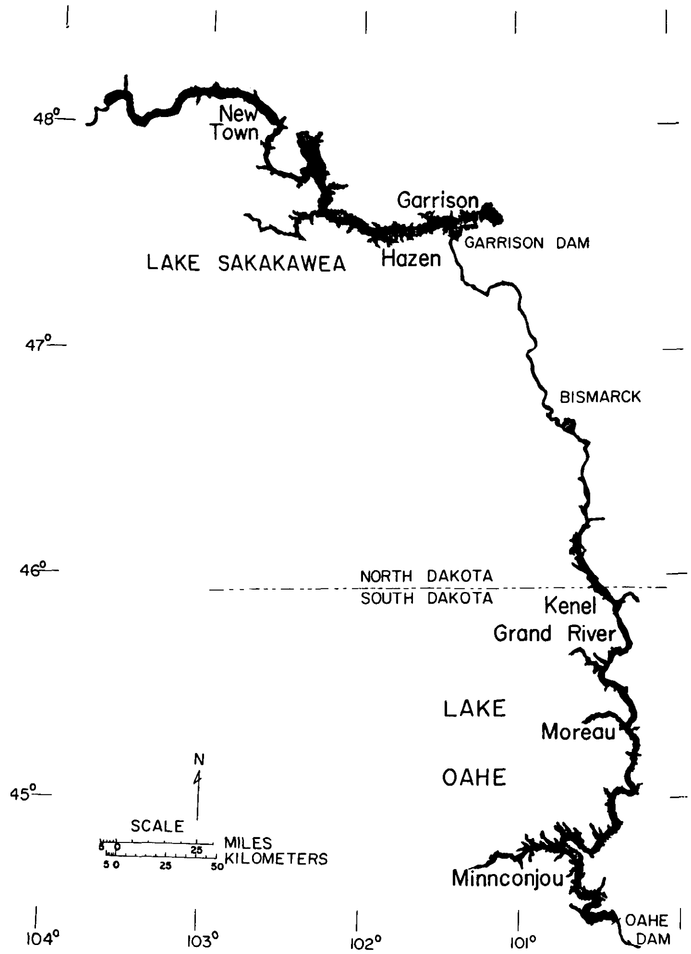

Fig. 1. *Seven study sites on shores of Lakes Oahe and Sakakawea, mainstem Missouri River reservoirs.*

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eliminate it. Reduced vegetative cover exposes the shore to enhanced erosion and reduces preferred spawning habitat for a number of important fish species in the reservoirs.

On the federally controlled land immediately surrounding Lake Sakakawea, a 6-month grazing period, May 1 to October 31, is permitted. On improved pastures the stocking rate allowed is one animal unit/15 acres, and on native grassland the rate is one animal unit/30 acres. Additionally, for maximum sustained production of the vegetation, one half the year's plant growth must remain after the grazing season. The stated regulations for grazing around Lake Oahe are somewhat different. Here the grazing period is May 1 to November 1, and winter grazing is permitted in lieu of summer grazing. Though stocking rates are not specifically stated, grazers are requested to comply with state regulations, strive to improve the grazing lands, and conform to all principles of good husbandry; overgrazing is not allowed (Operations Division, Corps of Engineers, Omaha District, personal communication).

Stated guidelines are obviously worthwhile for grazers. Parts of any grazed area will be more heavily utilized than others, and because of access to water, reservoir shores are areas of intense use. Because the shores are inundated regularly and the vegetation there is subject to drowning, it is somewhat more difficult to judge the impact of grazing. The ephemeral nature of the shore vegetation also makes it quite distinct from the upland steppe for which the grazing guidelines were actually written. The present study was done to document changes in shore vegetation as a result of cattle grazing along these two reservoirs.

Methods

The shore vegetation is a mosaic composed primarily of alien species that survive for various periods between high water. Vegetational changes occuring in these seral communities depend on such factors as source of disseminules, tolerance to flooding and/or water-logged substrates, timing of water level fluctuations in relation to phenological activities of plant species, and in some instances disturbance from cattle. Our study was done in 1976 following the record high water levels of 1975 during which most if not all the shore vegetation was drowned. Thus, most of the shore species encountered in our study became established late in 1975 or 1976. Doing the study in 1976 provided some measure of uniformity among the sites inasmuch as all the shore was quite depleted of species during 1975.

In 1973 and 1974 we constructed several cattle exclosures, seven of which were used in the present study. The exclosures are approximately 40 x 80 m (44 x 87 yd) with the long dimension perpendicular to the shoreline. All exclosures were constructed using steel posts planted about 10 m (11 yd) apart with four strands of barbed wire strung around the perimeter and clamped to each post. Corner posts were reinforced with additional stakes and wire. All exclosures have been checked twice yearly for maintenance needs. The exclosures were planned so that at least half the area inside was shore area and other half upland steppe. During the summers, when water levels are high, at least part of the shore area of each exclosure is inundated. Cattle have ready access to all the area around each exclosure.

At each sampling site (Fig. 1) we estimated plant canopy coverages within 2 x 5 dm (7.9 x 10.7 in) plots (Daubenmire 1959). We sampled 30 plots at meter intervals along a tape parallel to the shoreline inside the exclosure. A duplicate set of plots was analyzed along a tape outside the exclosure and the same distance from the shoreline. Where canopy coverages were estimated, we also collected plant materials for biomass estimates. These were done by clipping at ground level all living vegetation rooted within ten 0.1 m^2 (1.1 ft^2) plots inside each exclosure. For shrubs, only current year twigs and leaves were collected. These plots were spaced 2 m (6.6 ft) apart along the same tapes used for coverage estimates. All plant material collected was placed in paper sacks and air-dried in the field. In the laboratory the material was dried further at 70°C for 48 hr, then weighed to the nearest 0.1 g.

Voucher specimens of plants collected during this study were deposited in the University of South Dakota Herbarium.

Results and Discussion

The shore vegetation around both Lakes Oahe and Sakakawea is a mosaic of ephemeral plant communities that survive one or more years before being decimated by a combination of high water and/or cattle grazing. The shore communities consist primarily of seral species that become established either during the autumn or spring when water levels are low. At least part of the shore is inundated every year, eliminating some species annually, with more tolerant species persisting.

Minnconjou, Moreau, and Grand River sites on Lake Oahe occur on Pierre Shale-derived substrate which weathers into heavy clays or clay loams. The high clay content results in high water-holding capacity following inundation, or precipitation, but the same substrates become very hard and cracked when dry. Soil pH is above 7.0 at all three sites, and cation exchange capacities are between 29 and 31 meq/100 g with calcium and magnesium dominating the exchange complex. Owing to variable amounts of organic matter in the shore substrates, the amounts of phosphorus and nitrogen are variable, and not espcially high. The edaphic characteristics of the three sites are sufficiently similar that vegetational differences among the sites are not directly related to substrate characteristics. The similarity of each pair of stands was calculated using the familiar index of similarity:

$$I.S. = \frac{2c}{a+b} \times 100$$

where $I.S.$ is the index of similarity, a is the total number of species in one stand, b the total number of species in the second stand, and c the number of species shared by the two stands. The value is multiplied by 100 to express the index as a percentage. Using total floristic lists from the above three sites, the indexes of similarity are the following: Minnconjou and Moreau = 37%, Moreau and Grand River = 11%, and Minnconjou and Grand River = 10%. From ungrazed plots only, the indexes are the following: Minnconjou and Moreau = 40%, Moreau and Grand River = 34%, and Minnconjou and Grand River = 32%. From grazed plots only, the indexes are the following: Minnconjou and Moreau = 23%, Moreau and Grand River = 31%, and Minnconjou and Grand River = 27%.

Though chance is important in determining the composition of seral shore communities, there is considerable similarity among the three sites on Pierre Shale-derived substrates. Grazing reduced the similarities to some extent, as shown by the calculated indexes above. The Grand River site is the most heavily grazed of the three sites. It has the greatest abundance of *Solanum rostratum* and *Grindelia squarrosa*; both were more abundant on grazed plots at Grand River (Table 1). Important species on ungrazed plots at Grand River include *Bromus japonicus, Chenopodium album, Helianthus annuus, Melilotus spp., Polygonum achoreum,* and *Hordeum jubatum*. All but *Hordeum* were less abundant on grazed plots. Total coverage on grazed plots at Grand River was only slightly less than on ungrazed plots (Table 1). Total biomass, however, was reduced by nearly 50% on grazed plots at this site (Table 2).

Table 1. Average canopy coverages (%) of plants in grazed (G) and ungrazed (U) plots along shores of Lake Oahe and Sakakawea. Only those species are included that had an average coverage of at least 1% at one site.

	Sites and percent canopy coverages													
	Minnconjou		Moreau		Grand River		Kenel		Hazen		Garrison		New Town	
Species	G	U	G	U	G	U	G	U	G	U	G	U	G	U
Grasses:														
Agropyron repens (quackgrass) [1]										1			5	64
Agropyron smithii (western wheatgrass)		1					1							1
Agrostis hyemalis (ticklegrass)													4	
Alopecurus arundinaceus (garrison creeping foxtail)			1											
Beckmannia syzigachne (American sloughgrass)													1	
Bromus japonicus (Japanese chess)					2	19								
Enchinocloa crusgalli (barnyard grass)			2											
Hordeum jubatum (foxtail barley)			3	5	8	6	8	26	12	17	7	26	26	11
Panicum capillare (witchgrass)			1										1	
Poa palustris (fowl bluegrass)									1	5				
Poa pratensis (Kentucky bluegrass)									1					1
Sphenopholis obtusata (prairie wedgegrass)										9				
Shrubs and Forbs:														
Achillea millefolium (yarrow)									1					
Amaranthus albus (tumbleweed)		4				2								
A. graecizans (prostrate pigweed)		1												
Artemisia biennis (biennial wormwood)									3	2				
A. frigida (pasture sage-brush)									1					
Atriplex rosea (redscale)		8		7					1					
Chenopodium album (goosefoot)			3	2	1	6	48	27		25		1	27	10
C. hybridum (maple leaved goosefoot)							5	18						
Cirsium undulatum (wavy leaved thistle)												1		
Conyza canadensis (horseweed)								1	2	4				
Descurainia sophia (herb sophia)	1	1							1	5				
Grindelia squarrosa (gumweed)					37	18					1			
Hedeoma hispida (false pennyroyal)									1					
Helianthus annuus (common sunflower)		1			2	6								1
Iva xanthifolia (marshelder)										3			23	30
Kochia scoparia (fireweed)	2	2					9	27					1	
Lactuca serriola (prickly lettuce)						1								
Lepidium densiflorum (peppergrass)		1			1	3			2					
Medicago lupulina (black medic)											1			
Melilotus spp. (sweet clovers) [2]	2	7	6	1	2	13			1	47		2	4	
Plantago eriopoda (alkali plantain)														
Plantago major (common plantain)													3	
Polygonum achoreum (erect knotweed)			5	2	4	6		1	33	1	2		9	4
P. convolvulus (black bindweed)												1		
P. lapathifolium (nodding willow weed)			1	1			1		5	28	10	97	4	2
P. ramosissimum (bushy knotweed)		1	2	9			2	1				1	2	3
Potentilla norvegica (rough cinquefoil)									5	3	1	2	20	1
Ratibida columnifera (coneflower)									1					
Rumex crispus (sour dock)		6	10	47	3	1	3	12	1		2	6		
Rumex maritimus (golden dock)										1			11	
Salsola iberica (Russian thistle)				3				3						
Sisymbrium altissimum (tumbling mustard)										3				
Solanum rostratum (buffalo bur)	2	1			22	6								
Sonchus arvensis (field sow-thistle)										1				
Thlaspi arvense (pennycress)	4	11	6	9										
Verbena bracteata (prostrate vervain)			1											
Xanthium strumarium (cocklebur)		9	2	11										
Total cover, percent	11	54	43	97	82	87	77	116	72	155	24	137	141	128
Total number of species	8	16	18	14	14	15	11	13	25	20	11	13	17	13

[1] Plant nomenclature follows Van Bruggen (1976).

[2] Included here are *Melilotus albus* (white sweet clover) and *Melilotus officinalis* (yellow sweet clover).

Rumex crispus often dominates shore vegetation the first year following high water. It germinates and establishes on the bare shore in late summer as the water level recedes, remains in rosette form overwinter, then forms dense stands the following growing season. Cattle do graze the species. At the Moreau site *Rumex crispus* had 47% and 10% coverage on ungrazed and grazed plots, respectively. At Minnconjou it had 6% coverage on ungrazed plots and was absent from grazed plots (Table 1). At Moreau *Hordeum jubatum, Atriplex rosea, Polygonum ramossisimum, Thlaspi arvense,* and *Xanthium strumarium* were also important on ungrazed plots and were reduced or absent on grazed plots. Contrary to results obtained at Grand River and Minnconjou, both *Melilotus ssp.* and *Polygonum achoreum* were more abundant on grazed plots at Moreau. Total coverage at Moreau was 97% and 43% on ungrazed and grazed plots, respectively. Biomass at Moreau was 720 $g.m^{-2}$ and 19 73 $g.m^{-2}$ on ungrazed and grazed plots respectively (Table 2).

Table 2 Biomass ($g.m^2$) present in grazed and ungrazed plots of shore vegetation.

Condition of plots	Sites and biomass						
	Minnconjou	Moreau	Grand River	Kenel	Hazen	Garrison	New Town
Grazed	19	173	259	210	85	15	474
Ungrazed	378	720	458	606	478	1766	911

Minnconjou was the least productive site judged by both coverage and biomass estimates. Total coverage was 54% and 11% on ungrazed and grazed plots, respectively; and biomass was 378 $g.m^{-2}$ and 19 $g.m^{-2}$ on ungrazed and grazed plots, respectively. *Atriplex rosea, Amaranthus albus, Rumex crispus,* and *Xanthium strumarium* were all important on ungrazed plots and absent on grazed plots at Minnconjou. *Melilotus spp.* and *Thlaspi arvense* were also important on ungrazed plots and were considerably reduced by grazing (Fig. 2). No species encountered at Minnconjou was more abundant on grazed than on ungrazed plots.

The Kenel site occurs on a loess-derived substrate that has weathered into a relatively fertile silt loam soil. That the soil is quite fertile is attested to by not only soil analyses but also by the lack of response in production following addition of nitrogen, phosphorus, and potassium at the Kenel site (Hoffman and Stanley 1977). *Hordeum jubatum, Chenopodium album, C. hybridum, Kochia scoparia,* and *Rumex crispus* were all abundant on ungrazed plots. Total plant coverage was 116% and 77% on ungrazed and grazed plots, respectively, at Kenel (Table 1). Biomass estimates were 606 $g.m^{-2}$ and 210 $g.m^{-2}$ on ungrazed and grazed plots, respectively. *Chenopodium album* was much more abundant on grazed than on ungrazed plots and accounted for more than 50% of the coverage and biomass on grazed plots.

The three sites on Lake Sakakawea shore occur on glacial till-derived substrates having textures of loam at Hazen and clay loam at both Garrison and New Town. Floristic similarities among the three sites, lumping data from grazed and ungrazed plots and calculating as above for the Lake Oahe sites, yielded the following: Hazen and Garrison = 36%, Hazen and New Town = 41%, and Garrison and New Town = 24 %. The same indexes representing only grazed plots were the following: Hazen and Garrison = 28%, Hazen and New Town = 24%, and Garrison and New Town = 29%. Similarity indexes representing only ungrazed plots were Hazen and Garrison = 32%, Hazen and New Town = 42%, and Garrison and New Town = 30%. Floristically, ungrazed plots were more similar than grazed plots, consistent with results obtained from the Lake Oahe sites.

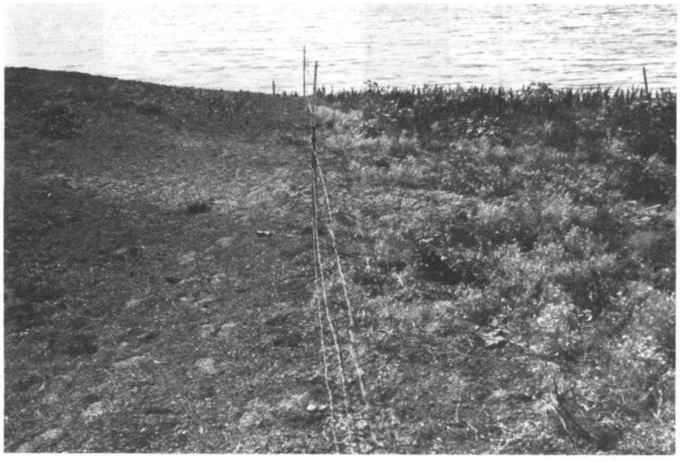

Fig. 2. *Shore vegetation at Minnconjou site. Inside exclosure, right, vegetation is dominated by* Rumex crispus, Xanthium strumarium, Melilotus spp., Atriplex rosea, *and* Thlaspi arvense. *Outside the exclosure, left of fence, cattle have removed most of the vegetation.*

Important species on ungrazed plots at Hazen were *Hordeum jubatum, Sphenopholis obtusata, Poa palustris, Chenopodium album, Descurainia sophia, Melilotus spp.,* and *Polygonum lapathifolium,* all of which were less abundant or absent on grazed plots. *Polygonum achoreum* was much more abundant on grazed plots with 33% coverage compared to only 1% coverage on ungrazed plots (Table 1). *Potentilla norvegica* was also somewhat more abundant on grazed than ungrazed plots. Total plant coverage at Hazen was 155% and 72% on ungrazed and grazed, plots respectively (Table 1). Biomass was 478 $g.m^{-2}$ and 85 $g.m^{-2}$ on ungrazed and grazed plots, respectively (Table 2).

Important species on ungrazed plots at Garrison were *Hordeum jubatum, Polygonum lapathifolium,* and *Rumex crispus.* All three species were much less abundant on grazed plots. Small amounts of *Grindelia squarrosa, Medicago lupulina,* and *Polygonum achoreum* were present only on grazed plots at Garrison. Total plant coverages at Garrison were 137% and 24% on ungrazed and grazed plots, respectively. Biomass was 1,766 $g.m^{-2}$ on ungrazed plots and 15 $g.m^{-2}$ on grazed plots. *Polygonum lapthifolium* accounted for much of the coverage and biomass on the ungrazed plots.

New Town was the only site at which total plant coverage was greater on grazed than on ungrazed plots, though the difference was slight. Biomass, however, exhibited the same trend as that of other sites: 911 $g.m^{-2}$ and 474 $g.m^{-2}$ on ungrazed and grazed plots, respectively. *Agropyron repens* dominated the ungrazed plots along with *Hordeum jubatum, Chenopodium album,* and *Iva xanthifolia*. Of these both *Hordeum* and *Chenopodium* were considerably more abundant on grazed plots (Table 1). *Potentilla norvegica, Iva xanthifolia, Chenopodium album, Hordeum jubatum* and *Polygonum achoreum* were all dominants on the grazed plots.

The dams and consequent reservoirs on the mainstem Missouri River were constructed for flood control, hydroelectric power, irrigation, downstream navigation, recreation, and wildlife habitat. The land area surrounding these reservoirs between high and low water levels (shore) supports a mosaic of vegetation that responds to fluctuating water levels, to cattle grazing, or to both. Shore vegetation is important in providing some habitat for terrestrial wildlife, spawning habitat for certain fish species, protection from accelerated erosion, grazing habitat for cattle, and it enhances the aesthetic quality of the shore environment. Thus, the major uses of the reservoir system, listed above, have added to them additional uses tied directly to the well-being of the reservoir shores. Just as the major uses of the reservoir system can be maximized one at a time, the uses made of the shore vegetation can only be maximized one at a time.

Cattle grazing is indeed one of the uses for which shore vegetation is intended, but not the sole use. While stocking rates are explicit, or implicit, in leases to grazers, it is well known that animals concentrate and exert more influence near a water supply than over most of the upland range. Results of the present study show rather clearly the impact of cattle grazing on shore vegetation of Lakes Oahe and Sakakawea. These results are consistent with observations made over a much larger area of the shores of these lakes. It is desirable to have shore vegetation present and to persist over a period of years. Assuming shore vegetation is sufficiently important to include in an overall management plan, the following suggestions are made to enhance shore vegetation. Grasses such as *Phalaris arundinacea* (reed canary grass), *Alopecurus arundinaceus, Alopecurus aequalis* (shortawn foxtail), and *Agropyron smithii* grow well on many shore sites. These species can be seeded to accelerate succession beyond the early seral stages (Hoffman and Stanley, unpublished data). Shore vegetation exhibits its greatest development when not perturbed by large fluctuations of water levels, or closely cropped by grazing cattle. Once established, the grasses listed above, along with a number of other species, withstand considerable inundation (Hoffman and Stanley, unpublished data). The volume of the six reservoirs of the mainstem Missouri River is large; it would be possible to minimize water level fluctuations within one reservoir each year with the remaining five reservoirs taking up the additional input of water during the spring and letting out more water during the late summer. Along with a program of rotational, or restricted, grazing, the minimal water level fluctuation would permit considerably more vegetation development than occurs presently. Two consecutive years of minimal water level fluctuations and restricted grazing would be desirable for a given reservoir shore. This regime could be rotated among the six reservoirs and ultimately provided shore vegetation of a higher quality than currently exists. There would be an added benefit of some predictability in the development of shore vegetation. At present, one cannot predict from year to year what the shore vegetation at a given site will be unless it was neither inundated nor grazed the previous year.

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Effect of Grasses and Soil Properties on Wind Erosion in Sand Blowouts

M.J. MALAKOUTI, D.T. LEWIS, AND J. STUBBENDIECK

Highlight: Many areas where wind erosion has been severe exist on the sandy rangeland in northcentral and western Nebraska. These areas are called "blowouts," and because of their large number and sometimes large size, forage production in the area is significantly reduced. It is necesary to reestablish vegetation on the blowouts in order to effectively manage the rangeland where they occur. Therefore, a study was conducted to determine the effectiveness of eight species of grass in revegetating the blowouts and in controlling wind erosion in them. The major factors related to stabilizing the soil surface in the blowouts were the amount of vegetative cover produced by the grasses and the length of time required for the protective cover to become established. In most cases the more vigorous rhizome producing grasses were most effective in becoming rapidly established and controlling wind erosion. However, none of the grasses studied were as effective in controlling wind erosion as was a mulch of prairie hay. A significant negative correlation existed between soil organic matter content and movement of sand by wind.

The Sandhills of Nebraska consists of about 52,000 km ^{2} in northcentral and western Nebraska (Seevers et al. 1975). Throughout this region thousands of hectares of rangeland exist where vegetation has been damaged or destroyed and the sand is subject to erosion by wind. These wind-eroded areas (blowouts) sometimes are as large as 50 hectares and represent a significant loss of forage production to the area. If left unprotected, the surface of the blowout is seldom able to become vegetated, the sand moved by the wind destroys surrounding grasses, and the blowout enlarges.

Blowout formation is brought about through removal of vegetative cover by overgrazing, prairie fire, or cultivation (Seevers et al. 1975). Mulches and/or vegetation are required to stop sand movement and heal the blowout. Many attempts to control wind erosion in various regions have been reported in the literature (Bagnold 1941; Chepil and Woodruff 1963; Chepil et al. 1963; Drullinger and Schmidt 1968; Eck et al. 1968; Behimaya et al. 1974; Woodruff et al. 1974). In general, these methods have been an attempt to establish some type of vegetation with or without the benefit of mulches. Mulches used range from manure and prairie hay to asphalt. Chemical compounds of various kinds have been evaluated in terms of their effect on wind erosion control by some workers (Armbrust and Dickerson 1971). Most researchers have reported varying degrees of success in blowout stabilization, but the degree of success is often dependent upon the type of vegetation established, the durability of the mulch, and the turbulence of the air flow across the blowout as affected by its orientation to the sand moving wind (Bagnold 1941; Baver et al. 1972).

The purpose of this study was to determine the relative effectiveness of eight grasses commonly grown in western Nebraska in revegetating blowouts and controlling sand movement. Correlation between some commonly measured soil properties and sand movement in the blown out areas was evaluated.

Methods and Materials

Twelve blowouts on the experimental range area at the University of Nebraska

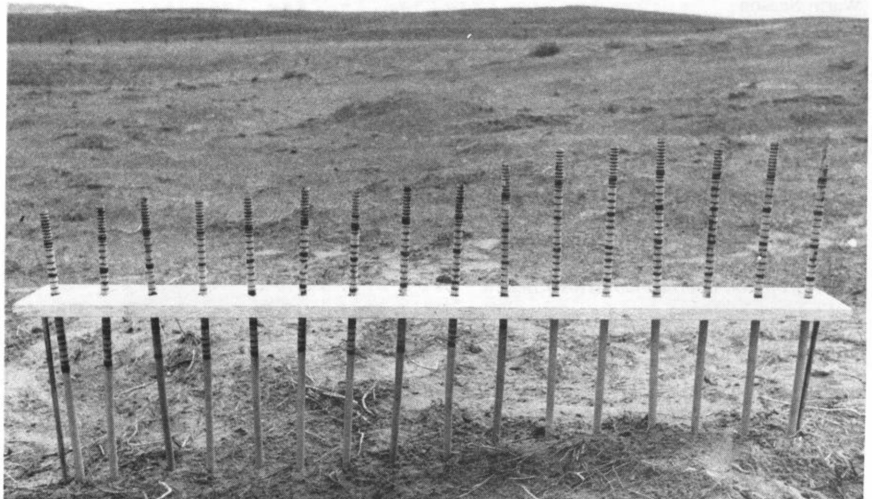

Fig. 1. *Device used to measure sand movement. The calibrated dowels were inserted through the leveled board to the sand surface at the time measurements were made. Afterward, both board and dowels were removed from the two permanetly placed steel rods.*

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Panhandle Station near Scottsbluff were selected as sites for stabilization studies. Some of the pastures in which the blowouts were located were composed of cool-season grasses while others were composed of warm-season grasses. Since cool- and warm-season grasses are managed separately, a separate experiment to study the effect of cool- and warm-season grasses was established. In order to minimize the effect of blowout shape on air turbulence, each site was shaped by bulldozing prior to fertilization and planting. Soil samples were taken from the A horizon or top soil of soils in the blowouts, before and after shaping, and of undisturbed rangeland outside the blowouts. Sampling sites were randomly located in the blowouts, and samples were taken with a sampling tube in the manner usually prescribed for a land user sampling the soil. Major physical, chemical and mineralogical properties of these samples were determined following procedures outlined by Jackson (1956) and the Soil Survey Staff (1972).

Four warm-season and four cool-season grasses were broadcast by hand in two separate experiments (Table 1). These were placed in a randomized complete block design and replicated 5 times. Each blowout area was handled as a replicate. A plot mulched with mature prairie hay was used as a check and compared with the grasses in each replicate in each of the two experiments. Both experiments received a uniform fertilizer treatment of 20 kg/ha nitrogen (34-0-0) and 20 kg/ha phosphorus (0-48-0) at seeding time, April 15, 1976. After the grasses had become established, they were fertilized with 20 kg/ha nitrogen in the form of ammonium sulfate.

The amount of sand moved by the wind was used as an indication of the rate at which soil erosion was taking place. Sand movement was determined each month using the device shown in Figure 1. This device a 124×11×2.5 cm board with 16 holes 2 cm in diameter) was placed on leveled steel rods (1 cm in diameter) at a randomly selected place in each plot at the time of each monthly measurement. Dowels with calibration marks were then inserted in the holes (7.5 cm apart) to the level of the sand. The change in distance between the board and the surface of the sand was recorded as sand added or removed. Measurements were made montly over a 2-year period. Stand density measurements were made in August 1976 and June 1977. A 0.1 m² frame was randomly placed at 60 locations within each plot and seedlings were counted within the frame at each location.

Results and Discussion

Stand density and frequency of occurrence as they relate to movement of sand are shown in Table 1. Among the warm-season grasses, prairie sandreed had the highest stand density and the greatest frequency of occurrence. In addition, less sand was moved in plots seeded with this species (Table 2). Only mulched plots had a lower amount of sand moved. The vigorous rhizomes of prairie sandreed and its adaptability to the environment of the blowout areas enabled this species to become established and spread rapidly and to more quickly and completely produce a cover on the bare sand.

Among the cool-season grasses, intermediate wheatgrass attained the greatest stand density, but was second to western wheatgrass in frequency of occurrence in the 1976 season and lower in frequency of occurrence than both western and crested wheatgrass in the 1977 season. No significant differences in the amount of sand moved in each plot were evident when the wheatgrasses were compared. Indian ricegrass had a low stand density and frequency of occurrence and offered the least protection to the soil, as evidenced by the amount of sand moved under its cover (Tables 1 and 2).

Comparison of species among both warm-and cool-season grasses suggests that those grasses that are most vigorous in the environment of the blowout attained the greatest stand density and frequency of occurrence. The more vigorous growth under the conditions of the blowout led to a greater protection of the surface from the erosive effect of the wind and a consequent lower amount of sand movement.

The grasses most effective in holding sand in place were prairie sandreed and intermediate wheatgrass. Among warm-season grasses, the advantage of prairie sandreed was especially apparent when amounts of sand removed from the plots following the time the grasses became established were compared (Table 2). Sand lovegrass and sand bluestem were the same in this respect and more effective in controlling sand removal than was little bluestem. Here again the more vigorous species had the advantage. The vigor of prairie sandreed under these conditions is probably due to the large number of rhizomes which it usually produces.

Among cool-season grasses, less sand moved under the wheatgrasses. When total sand movement was compared, little difference between the three species of *Agropyron* was evident. Yet, when sand removal only is considered, intermediate wheatgrass was better able to hold the sand down than crested wheatgrass. Indian ricegrass was least effective in the control of sand movement. Again, the advantage lies with the more vigorous species that could rapidly produce a stand

Table 1. Mean stand density (plants/m²) and frequency (%) of occurence of grasses in 5 blowouts used as replicates.

Grass Species	Stand density (plants/m²)		Frequency of occurrence (%)	
	1976	1977	1976	1977
Warm Season				
Prairie sandreed *Calamovilfa longifolia* Scribn.	18.9a [1]	20.9a	58a	57a
Sand lovegrass *Eragrostis trichoides* (Nutt.) Wood	18.3a	18.2b	56b	54b
Sand bluestem *Andropogon hallii* Hack.	18.0a	17.8b	55b	52b
Little bluestem *Schizachyrium scoparium* (Michx.) Nash.	14.8b	12.0c	55b	51b
Cool Season				
Intermediate wheatgrass *Agropyron intermedium* (Host) Beauv.	25.7a	22.3a	53a	51a
Western wheatgrass *Agropyron smithii* Rybd.	23.6b	18.3b	58b	57b
Crested wheatgrass *Agropyron desertorum* (Fisch.) Schult.	19.2c	12.9c	53a	57b
Indian ricegrass *Oryzopsis hymenoides* (Roem. and Schult.) Richer	12.7d	10.6d	46c	38c
Mulch-prairie hay	4.0 [2]	6.5		

[1] Mean values followed by the same letter are not significantly different at the 5% level of probability according to the Student-Newman Keul Test.
[2] Stand density results from seeds contained in mature prairie hay. These means were not included in statistical analysis.

Table 2. Mean amount of sand removal, sand added and total sand movement (metric tons/ha) in blowouts (replicates) seeded to different grasses.

Grass Species	Added		Removed		Total	
	April 76-May 77	July 76-May 77	April 76-May 77	July 76-May 77	April 76-May 77	July 76-May 77
Warm Season						
Prairie sandreed	401	214	516	225	917c	439c [1]
Sand bluestem	416	108	959	481	1377b	589b
Sand lovegrass	286	63	949	558	1235b	621b
Little bluestem	354	50	1243	765	1597a	815a
Cool Season						
Western wheatgrass	418	134	756	356	1174b	490b
Crested wheatgrass	389	112	797	437	1186b	549b
Intermediate wheatgrass	549	232	583	252	1132b	484b
Indian ricegrass	347	29	1169	749	1516a	778a
Mulch-prairie hay	734	382	0	0	734d	382d

[1] Mean values followed by the same letter are not significantly different at the 5% probability level according to the Student-Newman Keul Test.

density sufficient to keep sand movement at a low level.

None of the grass species were as effective in controlling sand movement as was the mulch. Hay used in mulching contained seeds of various grasses and other species native to Sandhills rangeland. Natural seeding from these grasses led to the stand density reported in Table 1. The effectiveness of mulch in controlling damage to the land surface by wind agrees with results reported by others (Chepil et al. 1963; Behimaya et al. 1974; Woodruff et al. 1974). In this study, the sand that moved under mulched treatment was all deposited on the plots while none was removed (Table 2). Apparently, the mulch protected the soil surface while acting as a barrier to reduce wind energy at the surface and allow sand particles to fall from suspension.

Table 2 further illustrates the value of mulch in controlling wind erosion in blowouts. Sand removal from the plots during April 1976 to May 1977 includes that part of 1976 before grasses were established on the plots, and during the time of strongest, most erosive wind in the area. Sand removal per hectare was, in most cases, nearly twice that of the July 1976 to May 1977 period. By July, the grasses were established and the northwesterly winds of spring had abated. When the strong winds came again in the spring of 1977, the established grasses were able to hold the sand with a degree of effectiveness relating to their stand density. During either period, however no sand was removed.

Sand removal from seeded plots occurred mostly from April through July of 1976 prior to establishment of grasses and from February to May 1977. Practically no movement of sand, either added or removed, occurred from August 1976 to February 1977. Therefore, the speed with which the grasses became established was a critical factor in the amount of sand moved from the plots. In late summer, vegetative density was adequate to hold sand in place. In late fall and early winter, the residues, along with typically more moisture in the soil and lower velocities of winds, kept sand removal to a minimum. In late February and March, spring winds again began to move sand. During this period, as in July 1976, there was a difference between grass species in ability to hold sand in place.

Analyses of the soils indicated that all were very sandy with very fine sand as the dominant particle size. However, all contained clay in an amount between 5.1 and 7.0 percent. Soils at the site were earlier considered to be within the Valentine Soil Series (Typic Ustipsamment) (Yost et al. 1968) but have more recently been placed within the Valent Soil Series (Ustic Torripsamment) (Soil Survey Staff 1972). Soils were alkaline (pH 7.7 to 8.2), low in cation exchange capacity (5.9 to 8.2 meg/100g), and low in organic carbon $<0.2\%$ in most replicates). Calcium was the dominant ion on the exchange complex. Illite was the dominant clay mineral in the clay fraction with lesser amounts of montmorillonite, kaolinte, and quartz evident. The sand fraction was dominated by quartz with between 12.5 and 19.1% potassium feldspars and between 7.1 and 11.6% plagioclase feldspars. A measureable amount of chorite was evident in all samples. The remainder of the sand fraction was composed of heavy minerals of which the micas, amphiboles, and pyroxenes constituted the major part.

Sand movement was correlated significantly with organic matter ($r = -88$ and -84 for warm-and cool-season experiments, respectively). In the cool-season grass plots, a significant negative relationship existed between cation exchange capacity and sand movement ($r = -88$). Percentage of clay was significantly correlated with organic matter content ($r = +.83$ and $+.92$ for warm-and cool-season experiments, respectively).

Conclusions

In spite of the relationship of some soil properties to the amount of sand movement, the major factor related to the control of wind erosion in the blowouts was the amount of cover on the sand and how quickly it became established. A definite advantage was noted for the grasses that produced more vigorous growth in the environment of the Sandhills, particularly prairie sandreed, as well as western and intermediate wheatgrass. Even under the cover of these grasses however, from 225 to 356 metric tons/ha of sand was removed from the plots. This amount of sand moving in the wind often buries or abrades seedlings that have become established.

Since mulched plots appeared to lose no sand, the most reasonable procedure to use in revegetating the blowout after it is shaped is to apply a prairie hay mulch containing a large number of seeds from the species mentioned. If this is not available, any type of mulch underseeded with prairie sandreed or intermediate wheatgrass appears to have considered potential for the control of blowouts in the rangeland of the Sandhills in Nebraska and surrounding states.

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Effect of Burning on Infiltration, Sediment, and Other Soil Properties in a Mesquite–Tobosagrass Community

DARRELL N. UECKERT, TERRY L. WHIGHAM, AND BRIAN M. SPEARS

Highlight: Burning had a minimal effect on rainfall infiltration and sediment load in runoff from a mesquite-tobosagrass community on slopes less than 1%. Most soil physical properties that affect infiltration on these heavy clay soils were not altered significantly by burning. Potential soil loss in runoff can be minimized by burning under relatively moist conditions. Larger soil aggregates were broken down by burning and had not returned to equilibrium on 5-year-old burns. Trends in levels of soil organic carbon, salinity, sodium, and potassium following burning varied with degree of soil cracking, which is a function of soil moisture.

Fire has proven useful in mesquite (*Prosopis glandulosa* var. *glandulosa*)–tobosagrass (*Hilaria mutica*) communities for removing dead honey mesquite, removing excessive accumulations of tobosagrass litter, increasing yield and utilization of tobosagrass, and for controlling honey mesquite, annual broomweeds (*Xanthocephalum dracunculoides*), and three species of cactus (*Opuntia* spp.) (Wright 1974).

Sharrow and Wright (1977a) reported that burning in March increased soil temperatures throughout spring and summer and increased the rate of soil nitrogen mineralization in tobosagrass communities. With adequate soil moisture, higher soil temperatures stimulated growth of tobosagrass with concomitant reductions in soil moisture and nitrates as compared to unburned controls. Neuenschwander et al. (1974) reported that soil organic carbon levels and bacterial counts increased following March burning and returned to normal within 6 years following burning in tobosagrass communities. Sharrow and Wright (1977b) concluded that burning too frequently (more often than once each 5 to 8 years) may deplete soil nitrogen reserves and reduce future plant growth.

Burning has reduced infiltration rates in soils of Missouri Ozark forests (Arend 1941), of chaparral communities of northern California (Sampson 1944), of Flint Hills tall grass prairie of Kansas (Hanks and Anderson 1957), and of Douglas fir (*Pseudotsuga menziesii*) forests of British Columbia (Beaton 1959). However, Scott (1956) reported increased infiltration on upland soils in California following fire as did Tarrant (1956) for a ponderosa pine (*Pinus ponderosa*) forest in eastern Washington. Veihmeyer and Johnston (1944) detected no impairment of infiltration rates on burned chamise (*Adenostoma* sp.) communities in northern California.

Burning has been reported to increase runoff and soil loss in woodland-chaparral-grass communities of the Sierra Nevada foothills (Rowe 1941), in the White Mountains of Arizona (Cooper 1961), in oak (*Quercus* sp.)-mountain mahogany (*Cercocarpus* sp.) chaparral (Pase and Lindenmuth 1971), and in chaparral communities of northern California (Sampson 1944). However, Veihmeyer (1951) reported that burning did not accelerate runoff or erosion on several watersheds with a variety of cover types, soils, topography and precipitation in northern California, as did Biswell and Schultz (1957) for ponderosa pine forests in northern California.

Mesquite-tobosagrass rangeland is an important grazing resource in Texas, New Mexico, Arizona, and northern Mexico (Neuenschwander et al. 1975). All effects of burning should be thoroughly evaluated for proper planning of burning schedules.

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This study was conducted to determine the effects of fire in a mesquite-tobosagrass community upon selected physical and chemical properties of the soil by comparing these properties on burns of different ages and on unburned plots.

Methods and Materials

Study Area

The study was conducted on the Spade Ranch, 22.5 km (14 miles) south of Colorado City in Mitchell County, Texas. The average annual precipitation is 50.2 cm (19.8 inches), about 78% of which falls between April and October. The winters are relatively mild with brief cold periods. The average daily maximum temperature in July and August is 36° C (97°F). The average annual evaporation is about 254 cm (100 inches) with approximately 66% occurring during the May to October period (Stoner et al. 1969).

The study area is occupied by the Stamford soil series which is mapped with the Dalby series in an undifferentiated unit. The Stamford series is classified as fine, montmorillonitic, thermic Typic Chromusterts while the Dalby series is classified as fine, mixed, thermic Typic Chromusterts. The Stamford series consists of nearly level areas (0 to 1% slope) of deep and well-drained calcareous clays (Stoner et al. 1969). The plant community on the study area has been described by Neuenschwander (1976).

Study plots were established within a 1-mile radius on large plots burned with headfires in March of 1975, 1974, 1972, or 1969, and on an unburned area. Plots were located on relatively homogenous Stamford soils with gentle slopes (0.6 to 0.9%). All plots were within a single pasture. Burning treatments were not replicated. Field data were collected during the late spring of 1974 and 1975.

Infiltration, Erosion and Selected Soil Physical Properties

A modified Purdue sprinkling infiltrometer (Bertrand and Parr 1961) was used to simulate rainfall at a rate of 11.4 cm/hr over a 40-minute period to randomly located Rocky Mountain infiltrometer microplots (0.236 m^2) (Dortignac 1951). Infiltration tests were replicated nine times on each age of burn and each unburned plot. Each microplot was prewetted with approximately 3.4 cm (1.3 inches) of water 24 hours prior to treatment to remove major differences in antecedent soil moisture and to eliminate soil cracking. The amounts of rainfall applied to each microplot and subsequent runoff were measured at 5-minute intervals during the 40-minute period. Infiltration was calculated as the difference between rainfall and runoff. The runoff from each microplot was collected and upon termination of the simulated rainfall application, was thoroughly agitated and subsampled in 0.95-liter quantities. These subsamples were allowed to settle for 2 weeks before the supernatant water was siphoned off. The sediment was oven-dried at 105°C for 24 hours, weighed and used as an index of erosion or sediment load. Antecedent soil moisture from each microplot was determined by the gravimeteric method (Gardner 1965) from three, 2.54-cm diam by 15-cm soil cores taken just outside the boundaries of each microplot.

Infiltration was also evaluated with a double-ring infiltrometer (Marshall and Stirk 1950) on each burned and untreated plot in early July of 1974 and 1975. Each randomly located microplot was prewetted with approximately 3.4 cm (1.3 inches) of water 24 hours prior to testing. Measurements were taken at 5-minute intervals during a 1-hour period. Double-ring infiltration tests were replicated nine times upon each treatment. We utilized this "ponding" approach, in addition to the "simulated rainfall" technique because tobosagrass communities commonly occur in depressions or concave sites which receive runoff from hillsides or convex sites. Water commonly accumulates in these concave sites following heavy rainfall.

Grasses, forbs, and litter were collected from each microplot after the infiltration tests to determine the effects of these factors on infiltration rates and sediment loads. The grasses and forbs were clipped as close to the soil surface as possible 1 day after infiltration tests and oven-dried at 63° C for 72 hours. Litter was collected with a modified Devac® insect vacuum and dried for 72 hours at 63° C. Oven-dried subsamples of litter were ground in a Wiley® mill, then ashed in a muffle furnace at 600° C for 8 hours for conversion of oven-dry weights to ash-free weights.

Five vertical, undisturbed soil cores, 5.4 cm in diam by 5.9 cm in length, were taken from the upper 5.9 cm of the soil profile in each microplot after removal of herbage and litter. From these cores, bulk densities were determined (Blake 1965), total porosity, capillary porosity and noncapillary porosity were measured using the tension-table method (Vomocil 1965), and hydraulic conductivity was determined by the constant-head method (Klute 1965).

The textural analysis was determined for the All horizon from each microplot cluster using the hydrometer method (Day 1965). Soil aggregate classes of > 3 mm, 3 to 2 mm, 2 to 1 mm, 1 to 0.5 mm, 0.5 to 0.25 mm and <0.25 mm were determined on duplicate bulk soil samples taken from the 0 to 1-cm increment of each microplot using the method for water stable aggregates (Kemper and Chepil 1965). Bulk soil samples for aggregate analysis were collected prior to the 1975 burn in addition to the post-burn sampling.

Soil Chemical Properties

Bulk soil samples taken from the 0 to 1, 1 to 2, and 2 to 4-cm increments from each microplot were used for determination of soil organic carbon (Allison 1965). Soil samples from the 0 to 2.54-cm increment in each microplot were used in preparing a saturated paste extract (Richards 1954) from which sodium and potassium contents (Fields et al. 1951) and soil salinity (Richards 1954) were determined. Soil reaction (Fields and Parrot 1966) was determined from the saturated paste using a Beckman® pH meter. Bulk soil samples for chemical analyses were taken prior to the 1975 burn in addition to the post-burn sampling.

Statistical Analyses

Data for all soil properties were analyzed with analyses of variance to determine differences among treatments. Variation among subsamples within treatments was utilized as the estimate of error. Duncan's multiple range test was used where appropriate to separate means (Snedecor and Cochran 1967). Linear stepwise multiple regression was used to determine which soil and site factors accounted for variations in infiltration rates and sediment loads within each treatment.

Results and Discussion

Infiltration

Initially, differences were observed in simulated rainfall infiltration rates among the burns of different ages. However, these differences seemed to be related to site differences rather than to effects of fire. Analysis of variance revealed that bulk density, noncapillary porosity, capillary porosity, total porosity, antecedent soil moisture, hydraulic conductivity, and fractions of sand, silt, and clay were significantly different among the sites. Analyses of covariance using bulk density, noncapillary porosity, capillary porosity, silt, sand, and antecendent soil moisture as covariables isolated no significant differences in total (entire 40-minute period) infiltration between treatments as determined with the modified Purdue sprinkling infiltrometer (Table 1). Similarly, there were no differences in infiltration rates among treatments within any of the 5-minute intervals during the 40-minute period of simulated rainfall, including the terminal infiltration rate. However, the double ring infiltrometer revealed significant differences in infiltration rates among treatments. Infiltration was lowest on recently burned areas and increased with time following burning (Table 1). Infiltration rates on burned areas approached that of unburned areas after 2 to 3 years (Table 1). The double-ring infiltrometer tends to exaggerate differences in infiltration rates, because of the constant hydraulic head effect.

Linear stepwise multiple regression was performed for each different age burn and unburned plot to determine the relationship between soil and site characteristics with infiltration rates. Regression equations showed that the most important factors affecting infiltration rates on these heavy clay soils were those dealing with the physical soil characteristics. Bulk density and noncapillary porosity were the most important of these characteristics. The larger aggregate classes were

Table 1. Adjusted (by covariance) means of Purdue sprinkling infiltrometer infiltration rates (cm/40 min), double-ring infiltrometer infiltration rates (mm/hr) sediment production (g/liter), mean standing vegetation (kg/ha) and ash-free surface litter accumulation (kg/ha) on different age burns and unburned plots in a mesquite-tobosagrass community in Mitchell County, Texas.

Treatment	Infiltration (Purdue) (cm/40 min)	Infiltration (Rings) (mm/hr)	Sediment (g/liter)	Standing vegetation k(kg/ha)	Litter (ash-free) (kg/ha)
None (1975)	5.3a[1]	130 de	0.06 a	4958 e	3517 g
None (1974)	6.1 a	98 cd	0.15 a	4110 cd	3008 f
5-year-old burn	5.3 a	150 e	0.11 a	4195 cd	1780 e
3-year-old burn	3.6 a	91 bcd	0.27 ab	3644 c	932 bc
2-year-old burn	3.1a	83 abc	0.23 ab	3729 c	1271 c
1-year-old burn	5.1 a	64 abc	0.43 b	4492 de	1398 de
Recent burn (1974)	6.4 a	46 a	1.28 c	381 a	424 a
Recent burn (1975)	2.8 a	79 abc	0.28 ab	1144 b	636 ab

[1] Means within a column followed by the same letter are not significantly different at the 90% level of significance.

next in importance. Standing vegetation and organic carbon, those factors affected directly by fire, were of lesser importance in affecting infiltration rates.

Standing Vegetation and Litter

Dry weights of vegetation and litter were reduced 91.2% and 85.7%, respectively, on the 1974 burn, and 77% and 82.2%, respectively, on the 1975 burn compared to dry weights on the respective unburned plots (Table 1). The biomass of standing vegetation on the 1-year-old burn exceeded that on the 2- and 3-year-old burns. However, it was composed largely of annual broomweed, due to relatively abundant fall (1974) and winter (1975) precipitation. The biomass of standing vegetation on the 5-year-old burn approached that on the unburned plots. Litter on the 1-year-old burn exceeded that on recent burns; however, litter accumulation on the 5-year-old burn was only 50% to 60% of that on the unburned plots (Table 1). Infiltration rates (double-ring method) increased exponentially as surface litter accumulation increased (Fig. 1).

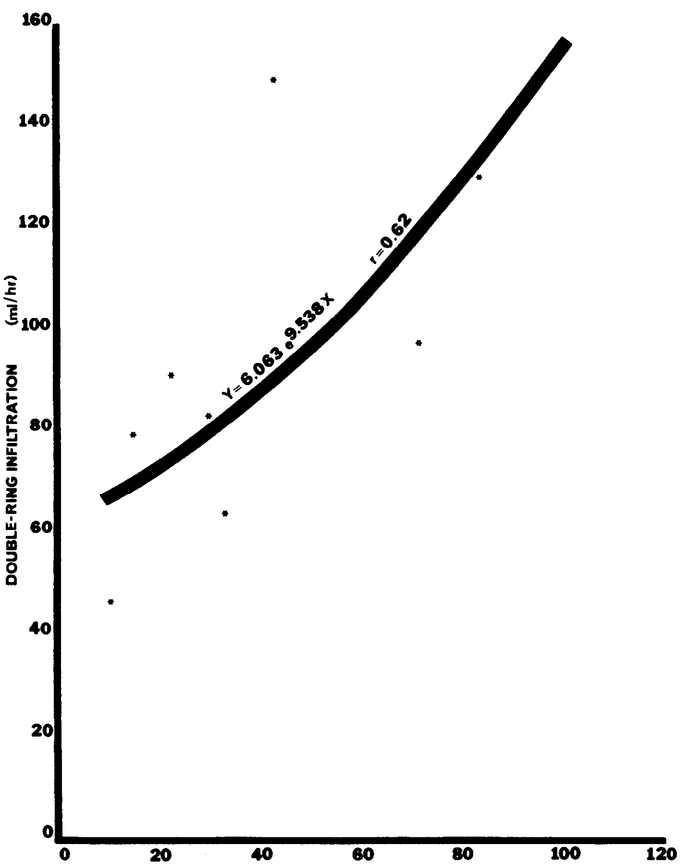

Fig. 1. Relationship between infiltration rates (mm/hr)(determined by a double-ring infiltrometer) and surface litter accumulation (g/microplot) on burns of different ages and on unburned plots in a mesquite-tobosagrass community in Mitchell County, Texas.

Sediment Load in Runoff

Sediment load in runoff increased significantly following fire in 1974, but not in 1975 (Table 1). Sediment load decreased rapidly the first year following the 1974 burn and continued to decrease as evidenced by the trend on 2-,3-, and 5-year-old burns. However, sediment loads from the 1975 burn and the 2- and 3-year-old burns were not significantly higher than the 5-year-old burn or that from unburned plots. The lack of protective litter seemed to account for most of the increased sediment load in the runoff immediately following fire. Sediment load in runoff increased exponentially as surface litter accumulation decreased (Fig. 2).

Sediment loads from recent burns (3-month-old) varied significantly between the 1974 and 1975 sampling dates. The sediment load from the 1974 burn, which occurred during relatively dry conditions (7.1 cm precipitation during 6-month period prior to burn), was 8.5 times greater than that of the unburned plot. The sediment load from the 1975 burn, which occurred under relatively moist conditions (20.2 cm precipitation during 6-month period prior to burn), was not significantly different from sediment load from the unburned area (Table 1). Thus, burning during relatively wet seasons may reduce the amount of

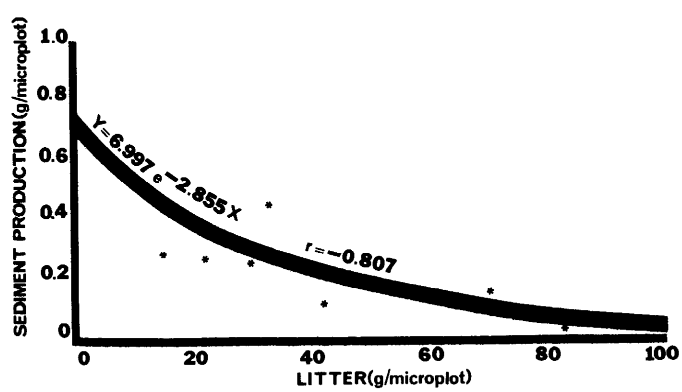

Fig. 2. Relationship between sediment production (g/microplot) and surface litter accumulation (g/microplot) on burns of different ages and on unburned plots in a mesquite-tobosagrass community in Mitchell County, Texas.

Table 2. Mean percentages of soil aggregates in six size classes in the surface cm on different age burns and unburned plots in a mesquite-tobosa community in Mitchell County, Texas.

Treatment	Aggregate size classes					
	>3 mm	3 mm–2 mm	2 mm—1 mm	1 mm–0.5 mm	0.5 mm–0.25 mm	<0.25 mm
None (1975)	45.3 d[1]	7.2 bcd	7.2 abc	5.4 ab	3.9 a	31.1 abc
None (1974)	43.0 d	8.3 d	9.7 d	7.8 bcd	4.4 ab	26.6 ab
5-year-old burn	26.2 ab	5.3 a	5.7 a	6.5 abcd	7.9 cd	48.5 d
3-year-old burn	22.7 a	6.7 bc	6.2 ab	4.9 a	3.9 a	56.1 e
2-year-old burn	31.6 bc	6.1 ab	5.6 a	5.5 abc	3.8 a	46.8 d
1-year-old burn	33.7 c	6.7 bc	8.4 cd	7.9 bcd	6.1 b	37.4 c
Recent burn (1974)	33.8 c	7.0 bcd	8.8 bcd	8.3 cd	9.4 d	32.8 bc
Recent burn (1975)	33.7 c	8.2 d	7.9 abcd	8.4 d	5.8 abc	36.0 c
Preburn (1975)	49.1 d	8.0 cd	7.9 abcd	6.0 abcd	4.2 ab	24.8 a

[1] Means within a column followed by the same letter are not significantly different at the 95% level of significance.

potential sediment loss. Exposure of the 1974 burn to the hot, dry spring and summer caused the soil to crack, be less compact, and generally be unprotected by standing vegetation and litter, which subjected it to more sediment loss.

Linear stepwise multiple regression indicated that standing vegetation alone accounted for over half of the variation ($P>0.05$) in sediment load on burned and unburned sites. Standing vegetation, the site factor radically affected by fire, was responsible for preventing erosion or sediment load in runoff. Soil bulky density and larger aggregate size classes were of secondary importance on both sites.

Soil Aggregates

Several size classes of soil aggregates were significantly altered by fire (Table 2). The >3-mm size class was reduced 15.4% by the 1975 burn compared to the preburn condition. The >3 -mm size class had not returned to normal levels on 5-year-old burns. The percentage of aggregates in the 3 to 2-mm size class decreased through the fifth year after burning, as evidenced by the trend recorded on burns of different ages.

The 2 to 1-mm size class was not affected by fire through the first year following burning. However, decreases were evident on 2-, 3-, and 5-year-old burns. The 1 to 0.5-mm size class increased somewhat initially after fire, but decreased on 2- and 3-year-old burns with an upward trend toward stabilization occurring on the 5-year-old burn. A similar trend was evident in the 0.5 to 0.25-mm size class.

The<0.25-mm aggregates increased considerably on the 2-year-old burn. This trend reversed on the 5-year-old burn, possibly due to the reaggregation of these particles into larger aggregates. This aggregate size class possibly increased upon breakdown of larger aggregates. Obviously, litter and standing vegetation protect the aggregates at the soil surface and prevent their destruction by raindrop splash and exposure to other climatic influences. This is supported by the strong positive correlation between litter and the >3-mm aggregate size class ($r=0.71$, $P>0.05$). The percentage of >3-mm aggregates increased as litter increased (Fig. 3).

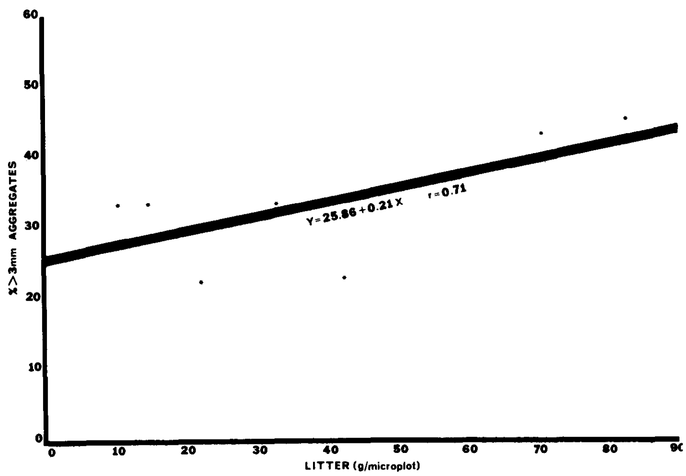

Fig. 3. *Relationship between mean percentage of > 3-mm soil aggregates and surface litter accumulation (g/microplot) on burns of different ages and on unburned plots in a mesquite-tobosagrass community in Mitchell County, Texas.*

Table 3. Mean levels of organic carbon (%), soil reaction (pH), salinity (mmhos/cm), sodium (meq/100g), and potassium (meq/100g) of different age burns and unburned plots in a mesquite-tobosa community in Mitchell County, Texas.

Treatments	Organic carbon (%)			Soil reaction[3] (pH)	Salinity[3] (mmhos/cm)	Sodium[3] (meq/100g)	Potassium[3] (meq/100g)
	0-1 cm	1-2 cm	2-4 cm				
None (1975)	2.69 c[1]	1.81 bc[1]	1.56 bc[1]	7.19 abc[2]	1.75 fg[2]	0.27 d[2]	0.08 cde[2]
None (1974)	2.62 c	2.03 cd	1.36 ab	7.57 def	1.57 cdefg	0.08 a	0.06 ab
5-year-old burn	2.58 c	2.26 def	1.62 c	7.45 bcde	1.29 abcdef	0.08 a	0.05 a
3-year-old burn	1.74 a	1.42 a	1.37 ab	7.84 f	1.71 defg	0.19 bc	0.06 ab
2-year-old burn	2.08 ab	2.07 cde	1.55 bc	7.63 ef	1.05 a	0.02 a	0.05 ab
1-year-old burn	3.23 d	2.41 ef	1.93 d	7.10 ab	1.72 efg	0.23 bcd	0.09 e
Recent burn (1974)	3.39 d	2.57 f	1.89 d	7.05 a	1.59 cdefg	0.04 a	0.09 de
Recent burn (1975)	2.73 c	1.31 a	1.24 a	7.53 cdef	2.01 g	0.23 cd	0.07 bcde
Preburn (1975)	2.26 bc	1.52 ab	1.22 a	7.21 abc	0.95 a	0.02 a	0.05 a

[1] Means within this column followed by the same letter are not significantly different at the 95% level of significance.
[2] Means within this column followed by the same letter are not significantly different at the 90% level of significance.
[3] Within upper 2.54 cm (1 in.) of soil

Organic Carbon

Soil organic carbon increased significantly in the upper 4 cm following the 1974 burn but was not affected by the 1975 burn (Table 3). A possible explanation for a different trend in 1975, compared to 1974, may be the differences in precipitation. In 1974, from October until the time of the burn in March, 7.1 cm (2.8 inches) of precipitation occurred. There was 20.2 cm (8.0 inches) of precipitation within that same interval in 1975. Increased precipitation in 1975 resulted in abundant soil moisture, thus a farily smooth soil surface without surface cracking. Less cracking and mulching of the Stamford clay during and after the 1975 burn apparently did not promote incorporation of unburned charcoal, ash, or residual litter into the soil surface layers. Organic carbon increased rapidly the year of the burn as the ash and unburned charcoal were incorporated into the soil immediately below the surface (as in the case of the 1974 burn). Thereafter, there was a slight decline in soil organic carbon the first year with a more rapid reduction in 2- and 3-year-old burns and a return to near equilibrium on the 5-year-old burn. A possible explanation for this trend may be the increased temperatures of the blackened soil surface following fire, which stimulates decomposer populations. These decomposers consume the organic carbon for their energy source and reach their population peaks by the end of the first year (Neuenschwander et al. 1974). Soil organic carbon is rapidly decomposed during the second and third years following burning. By 5 years after burning, 50 to 60% of the normal litter accumulation had been redeposited (Table 1) and soil organic carbon levels had returned to equilibrium. Neuenschwander et al. (1974) indicated that 2.65% soil organic carbon was the equilibrium state in tobosagrass communities, which is firmly substantiated by our data for the 0 to 1-cm increment.

Soil Reaction

The soil pH prior to the 1975 burn was 7.21, compared to 7.53 after burning (Table 3). This was not a significant change, and all differences in soil reaction seemed to be related to site differences rather than to fire. No trends in pH change with time lapse following burning were evident. Increases in soil pH following burning have been reported by Austin and Baisinger (1955), Marshall and Averill (1928), Barnette and Hester (1930), Heyward and Barnette (1934), Isaac and Hopkins (1937), and Nye and Greeland (1964).

Salinity

Salinity within the surface 2.54 cm (1 inch) of soil was increased by the fire in March, 1975. Salinity before the fire was 0.95 mmhos/cm, compared to 2.01 mmhos/cm after the fire and to the 1.75 mmhos/cm in the unburned plots. However, fire did not increase soil salinity following the 1974 burn compared to that on unburned plots. Since there was no surface cracking in 1975, the ash may have been confined to the surface, thus concentrating the salts. Under the drier conditions of 1974, the soil cracking and mulching would tend to diffuse the ash throughout the profile, thus giving lower salinity values for the surface 2.54 cm. No other temporal trends in soil salinity were evident. Salinity values appeared to vary with site variations among plots.

Sodium and Potassium

The sodium content of the soil after the 1975 burn was 0.23 meq/100g, compared to 0.02 meq/100g before the burn (Table 3). However, the soil sodium level in the 1974 unburned plot was not significantly different from that of the burn. This discrepancy in sodium content in the upper 2.54 cm following burning in a wet year compared to a dry year is probably also related to surface cracking. No other trends were detected with the lapse of time after burning.

Potassium contents were significantly different among soils from the different age burns and unburned areas (Table 3), indicating considerable site variation. Potassium levels in the upper 2.54 cm of soil of the 1974 and 1975 burns significantly increased compared to the unburned plot and the 1975 preburn sampling. The potassium content remained the same for 1 year and then declined the second year, probably due to a combination of plant use and leaching. Soil sodium, potassium, calcium, magnesium, and sulfur have been reported to increase following burning in several studies (Heyward and Barnette 1934; Austin and Baisinger 1955; Vlamis and Gowans 1961; Nye and Greenland 1964; Smith 1970).

Conclusions

Burning may slightly reduce infiltration rates of Stamford clay soils in tobosagrass communities. The effect does not appear to be significant under normal rainfall conditions, but may be on concave sites where runoff accumulates. Soil bulk density, noncapillary porosity, and large size classes of soil aggregates were the most important site characteristics affecting rainfall infiltration; and of these factors, only the large aggregates seemed to be significantly affected by March burning of tobosagrass. Standing vegetation played a role of lesser importance in affecting infiltration. Surface litter accumulation may be an important factor affecting infiltration in swales or concave sites, where water accumulates after rains.

Sediment loss in overland flow increased following burning of tobosagrass on slopes of less than 1%, but total soil loss was not significant and within 2 to 3 years the sediment load stabilized. Potential sediment loss may be minimized by burning when soils are relatively moist. Standing vegetation was the major factor regulating sediment load in runoff. Sediment load in runoff increased exponentially as surface litter accumulation decreased.

Larger sizes of soil aggregates break down following burning in tobosagrass communities, resulting in an increase in small aggregates. Recovery of aggregates to preburn levels had not occurred on a 5-year-old burn. The reduction of surface litter by fire was highly associated with the breakdown of large soil aggregates.

The degree of cracking of this heavy clay determined the trend in levels of soil organic carbon, salinity, sodium, and potassium. Ashes and unburned debris were incorporated and soil organic carbon levels increased when burns were conducted when the soil was dry and cracked; whereas when soils were moist, soil organic levels were not significantly changed. Burning in relatively wet years may increase salinity, sodium, and potassium in the upper 2.54 cm (1 inch) of soil; whereas in drier years, these substances are dispersed in the soil profile due to soil cracking. Soil pH was not significantly affected by burning.

In general, fire as a management tool in tobosagrass communities in West Texas does not adversely affect soil physical or chemical properties. Most effects are of a minimal nature and stabilization occurs within 3 to 5 years after the fire. Tobosagrass communities should be burned when soils are relatively moist, not only to assure better plant response, but also to minimize potential soil loss in runoff.

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Propagation of Nevada Shrubs by Stem Cuttings

RICHARD L. EVERETT, RICHARD O. MEEUWIG, AND JOSEPH H. ROBERTSON

Highlight: Stem cuttings of 54 Nevada shrub species varied in rooting capacity. Among those species most easily propagated were *Artemisia spinescens, Atriplex lentiformis, Ceratoides lanata, Grayia spinosa, Lepidospartum latisquamum, Prunus andersonii, Rosa woodsii, Salvia dorrii,* and *Vitis arizonica*. Semihardwood cuttings were superior to either softwood or hardwood cuttings in rooting success. Differences in rooting potential among cuttings of the same species taken from different sites were also apparent.

Native western shrubs are being used more and more in revegetation of disturbed wildland sites. Use of rooted cuttings to help meet the demand for such shrubs has been suggested by Plummer et al. (1968, 1974) and Nord and Gooding (1970). Vegetative propagation by rooted cuttings is a standard nursery practice for many shrub species that are difficult to grow from seed. Cuttings also provide a means by which large plants can be produced in a short period of time and superior plant material increased without loss of genetic integrity. Fundamentals of propagation by cuttings have been adequately discussed by Chadwick (1953), Edmond et al. (1964), and Hartmann and Kester (1968).

Shrub species from areas adjacent to Nevada have been successfully propagated from stem cuttings by Shreve (1951), Everett (1957), and Charles (1962), Chase and Strain (1966), Nord and Goodin (1970), and Carlson (1974). Stem cuttings of several shrubs from the southern Great Basin and northern Mojave Desert were shown to have the capacity to root, but no quantitative information was provided (Wieland et al. 1971). This paper reports a screening program to find shrub species that readily root from stem cuttings.

Methods

Stem cuttings were taken from 53 native species representing 32 genera and 15 families to determine rooting potential. Cuttings of individual species were taken from one or more sites within Nevada. Stem cuttings were taken of softwood (succulent, leafy shoots), semihardwood (leafy, matured annual or secondary growth), or hardwood (dormant or leafless secondary growth). Size of cuttings ranged from approximately 0.3 to 2.0 cm in diameter and 15 to 30 cm in length, depending on species and cutting type. Phenologic stage of the parent plant was noted at the time of collection; but, cuttings were not segregated as to age of the parent plant nor as to whether the cutting was from a lateral or a terminal shoot.

Cuttings were submersed in water immediately after they were severed from the parent plant. They were then wrapped in wet newspapers and put in a styrofoam box for transportation (4 to 72 hours) to a mist bench. Basal ends of the cuttings were wounded, dipped in a commercial talc preparation of 0.8% indole-3 butyric acid, and placed in coarse perlite on the mist bench. Bottom heat was not used because its effect on rooting success of cuttings from Great Basin shrubs was inconsistent among species and detrimental in some instances (Wieland et al. 1971). An intermittent mist system activated by evaporative demand was used to keep plants moist. A fungicide (Captan-50 WP)[1] diluted with water (0.41g/liter) was applied to the surface of the mist bench at a rate of 1.6 liters/m^2 at the time of planting to reduce cutting loss from disease.[2]

Cuttings of individual species were removed from the mist bench when large numbers had rooted or degenerated. A constant rooting period was not used because rate of rooting and susceptibility to mist bench pathogens varied considerably among species. A cutting was considered to be rooted if a root 1 cm in length was produced. Cuttings were left on the mist bench as long as 3 months, but 3- to 12-week periods were more common. All rooted cuttings were then placed in individual paper containers filled with sandy loam soil and transferred to the lathhouse for continued observation.

Results

Ability of cuttings to root varied among families and taxa of lesser rank including accessions (Table 1). Greater success in rooting was attained for cuttings from plants in the Caprifoliaceae (honeysuckle), Chenopodiaceae (goose-foot), Compositae (sunflower), Cornaceae (dogwood), Labiatae (mint), Oleaceae (olive), Rosaceae (rose), Rhamnaceae (buckthorn), Salicascae (willow), Saxifragaceae (saxifrage), and Vitaceae (grape) families than for plants in Ericaceae (heath), Garryaceae (silktassel), Leguminosae (pea), or Ephedraceae (ephedra). Genera in which two or more sampled species were readily propagated by cuttings include *Atriplex* (saltbush), *Artemisia* (sagebrush), *Salix* (willow), and *Symphoricarpos*

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[1] Use of trade or firm names is for reader information only, and does not constitute endorsement by the U.S. Department of Agriculture or Foresta Institute for Ocean and Mountain Studies of any commercial product or service.

[2] This publication reports research involving pesticides. It does not contain recommendations for this use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Table 1. Rooting success of cuttings by family, genera, and species.

Family genus species[1]	Number of accessions	Phenologic stages[2]	Cutting types[3]	Total no. of cuttings	Mean % rooted	Range in % rooted	Rooting period (wks)
Caprifoliaceae							
Sambucus							
caerulea	3	[4]1*,2,3	sh,h	185	4	0-14	4,12*
Symphoricarpos							
longiflorus	1	3	sh	25	56	0	4
oreophilus	1	5	sh	25	28	0	20
other species	1	4	sh	41	76	0	16
Chenopodiaceae							
Atriplex							
canescens	5	1,3,4*	so,sh*	305	11	0-48	4
confertifolia	5	4,5	so,sh	320	0	0	4
lentiformis	4	3*,5	so,sh*	206	32	0-68	3,4*
Ceratoides							
lanata	4	3,4*	so,sh*	235	16	0-63	3,4*
Grayia							
spinosa	16	1,2,3,4*,5,6	so,sh*,h	1,286	33	0-95	3,4*,8,12
Kochia							
americana	1	3	sh	45	0	0	12
Compositae							
Artemisia							
arbuscula	1	3	sh	100	0	0	4
cana	1	2	sh	48	21	0	8
spinescens	4	5,6*	sh,h*	201	22	3-60	4,8*
tridentata	2	3	sh	90	0	0	8
Baccharis							
glutinosa	1	5	sh	30	23	0	12
Brickellia							
multiflora	1	1	h	55	44	0	12
Chrysothamnus							
nauseosus	16	2,3,4*	so,sh*	1,018	9	0-63	4*,6,8
viscidiflorus	5	3,4	so,sh	275	0	0	8
Hymenoclea							
salsola	2	1,4*	sh	74	15	0-30	4*,8
Lepidospartum							
latisquamum	5	1,2*,3	sh*,h	346	30	0-96	4,8,12*
Pluchea							
sericea	1	5	sh	30	23	0	12
Tetradymia							
glabrata	1	3	sh	60	0	0	6
tetrameres	1	3	sh	50	0	0	8
Cornaceae							
Cornus							
stolonifera	2	1,3*	sh*,h	105	18	0-36	4*,8
Ephedraceae							
Ephedra							
nevadensis	2	1,4	sh,h	30	0	0	4,6
viridis	6	1,4*	so,sh*,h	299	2	0-9	8,10,16*
Ericaceae							
Arctostaphylos							
nevadensis	6	3,4,5,6*	sh	568	7	0-30	8,12*16
Garryaceae							
Garrya							
flavescens	2	1,3	sh	161	0	0	8
Labiatae							
Salvia							
dorrii	7	1,2*,3	sh	625	22	13-45	4,8,12*
Leguminosae							
Dalea							
fremontii	2	3	sh	85	0	0	8

(continued)

Table 1. (continued)

Family genus species[1]	Number of accessions	Phenologic stages[2]	Cutting types[3]	Total no. of cuttings	Mean % rooted	Range in % rooted	Rooting period (wks)
Oleaceae							
Menodora							
spinescens	1	6	sh	25	40	0	16
Rhamnaceae							
Ceanothus							
cordulatus	1	5	sh	20	10	0	20
greggii	2	4	sh	95	0	0	4,8
prostratus	1	4	sh	40	32	0	6
velutinus	3	4,5	sh	125	0	0	12
Rosaceae							
Amelanchier							
alnifolia	1	5	sh	40	0	0	4
utahensis	1	1	h	43	0	0	6
Cercocarpus							
ledifolius	1	4	sh	48	0	0	12
Cowania							
Mexicana							
stansburiana	3	1,3*	sh*,h	175	1	0-4	4
Holodiscus							
discolor	3	3,5*	sh	186	1	0-2	4,8,20*
Prunus							
andersonii	13	1,4,5*,6	so,rs,sh,h	1,459	26	0-85	4*,8,12,16
fasciculata	3	1,3	sh,h	97	0	0	4,8,12
virginiana							
demissa	3	1,2,5*	sh*,h	170	5	0-11	4
Purshia							
tridentata	2	4*,5	sh	110	4	0-9	4*,8
Rosa							
woodsii	3	1*	sh,h*	261	43	2-65	4
Salicaceae							
Salix							
bebbiana	1	4	sh	55	89	0	4
exigua	7	1,3,4*,5,6	rs,sh*,h	444	86	30-98	4*,8,20
myrtillifolia	1	3	sh	62	54	0	4
other species	6	1*,3,4	sh,h*	411	88	67-100	4,8,12*,20
Saxifragaceae							
Ribes							
aureum	4	1,4,5*,6	sh*,h	177	7	0-28	4*,8,12
cereum	2	1,5*	sh*,h	70	1	0-3	8,20*
viscosissimum	1	5	sh	15	46	0	4
Vitaceae							
Vitis							
arizonica	3	2*3,5	sh	133	60	30-100	2,12*

[1] Nomenclature after A.H. Holmgren and J.L. Reveal, 1966.
[2] Phenology stage: 1, Dormant; 2, Leaf growth; 3, Twig growth; 4, Flowers; 5, Seed; 6, Predormancy quiescence.
[3] Cutting type: so–softwood; sh–semihardwood; H+hardwood; rs–root sprout–soft wood.
[2]* Indicates an estimate of the best treatment, as not all possible treatment combinations were tested.

(snowberry). Cuttings from species in *Amelanchier* (serviceberry), *Chrysothamnus* (rabbitbrush), *Ephedra* (joint-fir), and *Tetradymia* (horsebrush) genera did not root readily under test conditions.

Rooting success was highly variable among accessions of individual species as previously reported by Komissarov (1968). Species that were most easily propagated by cuttings from a number of selected accessions were:

Atriplex canescens (fourwing saltbush)
Atriplex lentiformis (big saltbush)
Artemisia spinescens (bud sagebrush)
Ceratoides lanata (common winterfat)
Grayia spinosa (spiny hopsage)
Lepidospartum latisquamum (wooly scalybroom)
Prunus andersonii (Anderson peachbrush)
Rosa woodsii (rose)
Salvia dorrii (sage)
Salix sp. (willow)
Symphoricarpos sp. (snowberry)
Vitis arizonica (canyon grape)

Cuttings from *Artemisia cana* (silver sagebrush), *Baccharis glutinosa* (seepwillow Baccharis), *Brickellia multiflora* (Inyo brickellia), *Ceanothus prostratus* (squawcarpet ceanothus), *Cornus stolonifera* (redosier dogwood), *Menodora spinescens* (spiny menodora), and *Ribes viscosissimum* (sticky currant) also had high rooting success, but too few accessions were collected to assess species' rooting potential.

Cutting type was also important in rooting success. Semihardwood cuttings were superior to either hardwood or softwood cuttings when phenologic stage and collection site were the same. Softwood cuttings were very susceptible to disease and several accessions were lost during transport or on the mist bench. In most instances, hardwood cuttings did not root as rapidly or as consistently as semihardwood cuttings. Semihardwood cuttings from root sprouts of Anderson peachbrush rooted successfully when stuck directly in soil-filled containers and placed under mist conditions.

The best phenologic stage for rooting success was not always the same among species (Table 1). In general, cuttings taken during vegetative and reproductive phenologic stages rooted better than cuttings taken during dormancy. Notable exceptions to this generality were cuttings from bud sagebrush, rose, and elderberry (*Sambucus caerulea*). Species that rooted well from cuttings also seemed to have the highest survival rate following transplanting into containers, but this is only an observation.

Discussion and Conclusions

Rooting results for these shrubs were in general agreement with previous findings for other species in the tested plant genera. Cuttings from species of sage, burrobrush (*Hymenoclea* sp.), pluchea (*Pluchea* sp.), saltbrush, snowberry, and willow were easily rooted as previously reported (Everett 1957; Chase and Strain 1966; Nord and Goodin 1970; Ellern 1972; and Carlson 1974). Rooting capacity of big saltbush, spiny hopsage, and common winterfat was similar to that reported by Wieland et al. (1971), but we did not get rooting from cuttings of shadscale (*Atriplex confertifolia*), Gray Kochia (*Kochia americana*), or green ephedra (*Ephedra viridis*), as reported. Differences in plant materials and propagation methods were likely causes for conflicting results.

Although some species did not root well from cuttings, they might if different collection and propagation procedures were used. If cuttings were collected from plants growing under excellent conditions and if transportation time to the mist bench were reduced, rooting success of several species might be increased. Hormone, misting, and perlite combinations used in this study were probably not the best for rooting stem cuttings of tested species. Cuttings from some species, such as shadscale and common winterfat that rapdily degenerated under misting, would be more likely to root successfully under less moist conditions (Wieland et al. 1971). Also, some rooting ecotypes of apparently nonrooting species may exist but were not sampled.

Rooting results for tested species may not be the best that could be attained, but they do give an indication of species' rooting potential. More information is needed of the effects of certain factors—season of collection (Hess 1963), ''plant juvenility'' (Hackett 1964), phenologic stage, stem position (Hartmann and Kester 1968), bottom heat (Chadwick 1953), and hormones—on the rooting capacity of native shrubs before the best propagation procedures can be formulated for each species.

The variability in rooting success among accessions of a species points out the necessity for careful selection of cutting stock. Rooting success should be substantially improved once superior rooting ecotypes are selected and cutting made under excellent conditions (Hess 1963; Komissarov 1968).

Large plants of several shrubs (Anderson peachbrush, bud sagebrush, common winterfat, sage, snowberry, spiny hopsage, and willow) were obtained in 3 to 12 weeks after transplanting them into containers. These plants would have taken as long as 6 months to grow to the same size from seed. More efficient growth of native plant materials should lower propagation costs and make native materials easier to obtain for use in reclamation and horticulture.

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Forage Intake by Grazing Livestock: A Review

F.J. CORDOVA, JOE D. WALLACE, AND REX D. PIEPER

Highlight: A wealth of experimental data has been accumulated on quantitative intake of pen-fed livestock; such information has been widely employed to develop a keener nutritional knowledge of such animals. Data of this type are, however, distressingly lacking for grazing livestock. The procedures used for measuring intake by animals under grazing conditions have often been disappointing, and many have provided unreliable data. Forage intake measurements with grazing livestock are more commonly expressed as g DM or OM/$W_{kg}^{.75}$ or simply as a percent of body weight. Most estimates of intake for cattle and sheep grazing ranges in Western United States fall within the range of 40 to 90 g DM/$W_{kg}^{.75}$ or from 1 to 2.8% of body weight. Intake usually decreases with advancing plant maturity.

Yield of animal products from grassland areas depends on a number of associated factors. To improve forage utilization, it is necessary to measure, or at least estimate, these components. One of the most important of these components is the quantity of forage consumed by grazing livestock. Consumption and digestibility of grazed forages has been an area of interest and challenge to nutritionists, but research in this area was somewhat neglected in the United States until increased grain prices and decreased feed grain availability caused a renewed concern in forage utilization. Two reasons for the necessity of more research on this subject might be that, first, higher producing animals are likely to be those consuming most, and second, that economic returns are often limited because voluntary intake by livestock may restrict the amount of grassland products that can be utilized.

The purpose of this review was to consider methods used in estimating and expressing intake levels of grazing livestock. Moreover, much of the existing data on intake measurements was consolidated and expressed on a common basis.

Ways of Expressing Levels of Intake

Traditionally, most investigators have expressed forage organic matter intake (OMI) or a dry matter intake (DMI) relative to body weight (Langlands 1968), as a percent of body weight (Van Dyne and Meyer 1964), or simply in pounds or kilograms per animal per day (Streeter et al. 1974). Since intake by grazing animals must vary with some function of body weight, perhaps a better criterion for expressing intake might be its relation to maintenance in order to adjust for differences among animals (Moore and Mott 1973), although this practice does not remove variations among animals of similar weight with true metabolic differences (Arnold 1975). When differences in live weight result from differences in age, breed, or previous level of nutrition, no single relationship may be generally applicable (Langlands 1968).

The expression of intake per unit of metabolic body weight, i.e., w_{kg}^{75} (MBW) does, however seem adequate for most situations. In plotting intake against body size, Crampton et al. (1960) and Blaxter et al. (1961) both found a better fit for data when weight was coverted to MBW. Other workers have differed in opinion. Langlands (1968) calculated an exponent of 0.82 for the relationship between OMI and body weight of sheep of different breeds varying in age from one to two years. He also found that, within a breed, intake was more closely related to age than to body weight (Langlands 1968). However, the same author later reported that the mean DMI of six and 66 month-old wethers was 633 and 987 grams, respectively; but when intake of both groups was expressed on the basis of MBW, the difference in intake became negligible, i.e., 70.3 and 70.1 g/MBW, respectively (Langlands 1969).

The above expression is not routinely used by researchers in the United States, but it appears that there is an international trend to express intake on a MBW basis, although slight differences do occur. Researchers in Europe (Blaxter 1962), Australia (Minson 1973), and Canada (Heaney et al. 1968) have expressed intake in terms of g/$w_{kg}^{.734}$, g/$W_{kg}^{.73}$, and g/$W_{kg}^{.75}$, respectively. Further consideration of these relationships has been given by Pfander (1970) and Waldo (1970).

Methods for Estimating Intake

No method has been devised by which intake of grazing livestock can be accurately quantified. Thus, some type of estimation is employed where these data are desired. The types of estimations currently used are generally referred to as "indirect techniques" and basically fall into two categories, i.e., ratio techniques and index procedures. Ratio techniques involve the calculation of digestibility and fecal output data through their ratio to an "indigestible" indicator or marker. Indicators may occur naturally in the forage (internal indicator) or may be administered in known amounts (external indicator). Internal indicators are more frequently used for estimating digestibility, while external indicators are used more in fecal output estimates. Once digestibility and fecal output data are established, intake may be calculated from the simple equation:

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organic matter intake = fecal organic matter output/% organic matter indigestibility. The same procedure is used for estimating dry matter intake although most workers prefer the use of organic matter because of the relatively high ash content in range and pasture forages. Index procedures generally relate level of intake or digestibility to some component in the feces through a regression equation. The most common fecal component used to date has been nitrogen (N). Since some measure of digestibility is often required to calculate intake by grazing animals, most studies of this type have dual objectives of estimating both digestibility and intake.

Monographs detailing advantages and disadvantages of different methods utilized to arrive at estimates of fecal production, forage digestibility, and/or intake are those by Streeter (1969) and Theurer (1970). A thorough review on the properties, evaluation, and application of external and internal indicators was carried out by Kotb and Luckey (1972). Schneider et al.(1955) discussed the disadvantages of estimating intake by using agronomic measurements such as forage yield before and after grazing. Where this approach has been used, problems associated with trampling, variable forage growth, selective grazing and number of plots needed have usually been sufficient to cause somewhat questionable results. Likewise, lack of precision has seriously restricted the use of many other techniques intended to relate intake to other animal or forage characteristics, e.g., animal performance (Davis et al. 1970), number of mastications (Bjugstad et al. 1970), water consumption (Hyder et al. 1968), and fecal-excreted compounds such as iron, copper, magnesium, and silica (McManus et al. 1967).

The chromogen method as proposed by Reid et al. (1950) has been investigated by several workers using hand-fed cattle, but its application with grazing animals appears dubious because of large daily variations of plant chromogen concentration in feces (Reid and Kennedy 1956) and in chromogen recovery (Kennedy et al. 1959).

Lignin Ratio Technique

The lignin ratio technique has been widely used by American workers to estimate digestibility by grazing cattle and sheep (Wallace and Van Dyne 1970), in spite of many serious imperfections in the procedure (Van Dyne 1969). Sometimes it has been less reliable than the chromogen-ratio (Connor et al. 1963; Ridley et al. 1963). Occasionally, lignin has given reasonable estimates, but more frequently there have been strong indications that it yields seriously biased results (Handl and Rittenhouse 1972; Scales et al. 1974).

Analytical procedures used for determining lignin are cumbersome and complex, but one of their most negative features was shown by Wallace and Van Dyne (1970). After reviewing the apparent digestibility of lignin in various forages by different classes of animals using different analytical methods, they concluded that lignin may be digested to a large extent, particularly in immature forages.

More reliable methods for estimating digestibility under range conditions are probably the fecal nitrogen index, or a combination of in vitro techniques for estimating forage digestibility in diets selected by esophageal-fistulated animals, with either the total fecal collection method or the chromic oxide ratio for estimating fecal output (Scales et al. 1974; Lake et al. 1974; Arnold 1975).

Fecal Nitrogen Index Procedure

This method was developed partly as an alternative to methods that required sampling of forage consumed to determine digestibility. Greatest use of the method has been on improved pastures. Detailed reviews of the fecal N method have been carried out be Arnold and Dudzinski (1963), O'Donovan et al. (1967), and Streeter (1969). Van Dyne and Meyer (1964) and Langlands (1969) described different ways this technique can be used. Sources of error in fecal N regression techniques have been discussed by Greenhalgh and Corbett (1960) and Lambourne and Reardon (1963).

The foundations for this method are that fecal N is primarily of body origin and that metabolic fecal N is excreted in proportion to the quantity of dry matter consumed or digested (Blaxter and Mitchell 1948). Observations made in England (Raymond 1948) and New Zealand (Lancaster 1949) showed a positive relationship between digestibility of forage and N concentration in the feces of grazing livestock. Later, both workers developed regression equations from feeding trials which could be used to estimate digestibility by grazing animals (Lancaster 1954; Raymond et al. 1954). Wallace and Van Dyne (1970) enumerated a series of problems encountered in transposing results from conventional digestion trials to freely grazing animals, giving a simplified, hypothetical example of how the fecal N method is utilized for estimating digestibility.

Investigators following the original findings of Lancaster (1949; 1954) who were also studying intake found some application of the fecal N index approach. In the latter case, however, total fecal N excretion (rather than N concentration) and/or a feed-to-feces ratio factor (I/F) were necessary (Lancaster 1954). In these instances, total fecal collections or their estimation was required.

Errors associated with regression equations found in several studies have indicated that their application could be limited to cases where very large differences in intake or digestibility exist. Different trials have consistently shown coefficients of variability ranging from 13% (Jeffery 1971) to 9% (Lancaster 1954). Minson and Raymond (1958) regarded an error of 12% as being so large that the technique becomes useless except to measure very large differences in intake. Yet, relationships between I/F and N have been used widely (Table 1). Explorations of multiple regressions using fecal output (F), nitrogen concentration (N), and their product (FN), as independent variables, have produced relationships of different forms (e.g., quadratic, inverse, logarithmic), which have generally yielded better results than those adapting a simple form, i.e., $I=a+b$ FN. Lambourne and Reardon (1963), working with a wide range of fresh pastures covering all seasons, obtained a curvilinear regression equation that explained variation in intake more precisely than simple linear regression equations calculated for pastures that had been divided according to season (Table 1). Likewise, using data from 35 conventional digestion trials with sheep, Arnold and Dudzinski (1963) found that results could be grouped homogeneously due to botanical or seasonal differences. Specific groups provided highly significant linear equations of the forms $I = b\,F + c\,FN$, and $I = a + b\,FN$. A quadratic expression ($I = b\,F + c\,FN + d\,FN^2$) accommodated a majority of the data but was less precise than simpler forms. A further expression: $I = a + b\,FN^2 + c\,N$, although far from being universally adequate, was generally more precise than existing formulae (Arnold and Dudzinski 1963).

It should be noted that a practical limitation of the method for determining intake might be the requirement of a total fecal collection by grazing animals, or its estimation from an external

Table 1. **Observations on the use of regression analysis to predict intake from fecal nitrogen with grazing animals.**

Reference	Location	Animal	Type of pasture	Regression equation[a]	$S_{y.x}$ [b]
Lancaster, 1954	New Zealand	Cows	Mixed improved pastures (general)	$Y=1.02+0.97N$	0.39
Vercoe et al., 1961	Australia	Sheep	Improved pastures (general)	$Y=0.98+0.86N$	0.22
Vercoe et al., 1962	Australia	Sheep	Improved pastures (spring)	$Y=1.34+0.72N$	0.85
Vercoe et al., 1962	Australia	Sheep	Improved pastures (summer)	$Y=1.24+0.61N$	0.70
Vercoe et al., 1962	Australia	Sheep	Improved pastures (autumn)	$Y=0.84+0.79N$	1.07
Vercoe et al., 1962	Australia	Sheep	Improved pastures (winter)	$Y=1.67+0.12N$	0.92
Elliott & Fokkema, 1961	Rhodesia	Cows	Veld grassland (general)	$Y=0.48+1.04N$	c
Greenhalgh & Corbett, 1960	Scotland	Steers	Grasses, first growth	$Y=1/(0.55-0.11N)$	c
Kennedy et al., 1959	New Zealand	Cows	Improved pastures (general)	$Y=-1.74+10.6\log N$	0.32
Holmes et al., 1961	England	Sheep	Late ryegrass	$Y=1/(0.56-0.13N)$	c
Minson & Kemp, 1961	England	Sheep	November grass swand	$Y=1/(0.73-0.12N)$	c
Lambourne & Reardon, 1962	Australia	Sheep	Fresh pasture (entire plants)	$Y=0.21+1.37N$	c
Lambourne & Reardon, 1963	Australia	Sheep	Fresh pasture (all seasons)	$Y=3.66-1.39N+0.36N^2$	0.55
Lambourne & Reardon, 1963	Australia	Sheep	Fresh pasture (summer)	$Y=0.83+0.88N$	0.58
Lambourne & Reardon, 1963	Australia	Sheep	Fresh pasture (winter)	$Y=0.12+0.86N$	0.42
Arnold & Dudzinski, 1963	Australia	Cattle	Improved pastures (general) from Greenhalgh et al., 1960	$I=17.2+0.2FN+0.2FN^2-3.8N$	c
Arnold & Dudzinski, 1963	Australia	Cattle	Improved pastures (spring and summer)	$I=11.7+1.5F-1.3FN+0.4FN^2+2.7N-1.0N^2$	c
Hutton & Jury, 1964	New Zealand	Cows	Fresh pastures (general)	$Y=1.35N$	0.43
Arnold & Dudzinski, 1967[b]	Australia	Sheep	Improved pastures (general) from Arnold & Dudzinski, 1963	$I=63.0+106.0FN$	64 g
Minson & Milford, 1967	Australia	Sheep	Rhodes grass, cv. Callide	$Y=6.8+179.8N$	1.60
Minson & Milford, 1967	Australia	Sheep	Rhodes grass, cv. Sanford	$Y=2.2+171.6N$	1.40
Jeffery, 1971	Australia	Sheep	Kikuyu pastures	$I=-37.0+170.0FN-0.45F^2$	112 g
Jeffery, 1971	Australia	Sheep	Kikuyu + N fertilizer	$I=109.0+170.0FN-0.45FN^2$	112 g
Rao et al., 1973	Kansas	Steers	Bluestem pastures	$I=1.13+1.75FN$	c
Moran, 1976	Australia	Cattle (Zebu & Hereford)	Improved pastures (general)	$Y=2.04-0.19N^2$	c

[a] Y is feed-to-feces ratio; N=nitrogen; I=intake; F=fecal output.
[b] Standard errors given in percentage units.
[c] Data not available.

indicator. While problems observed in using bagged animals for fecal collections on open range are reviewed later, it should be pointed out that, perhaps due to its many limitations, the fecal N method is better suited for digestibility than for intake estimates (Cordova 1977). In studies with cattle grazing sandhill ranges in Colorado, fecal N was an exceptionally valid estimator of digestibility, e.g., as much as 93% of the variation in in vivo digestibility was explained by differences in fecal nitrogen (Wallace and Van Dyne 1970; Scales et al. 1974).

Total Fecal Collection.

This is the oldest method for determining intake and/or digestibility of forages by livestock, and it is commonly referred to as the ''conventional'' or ''standard'' method (Schneider et al. 1995). Under controlled conditions it involves complete records of feedstuffs consumed and total collection of feces voided to determine digestibility. When used under grazing situations the method may be inversed for estimating intake. Intake is estimated by combining determinations of digestibility of pastures grazed by animals with measurements of fecal output. Digestibility may be estimated in vitro from samples collected by esophageal-fistulated animals, or by using the fecal N method if a suitable regression equation is available (Arnold and Dudzinski 1963).

The part of the method concerning total fecal collection is supposedly most problematic, although measurements of total fecal output under grazing conditions have been carried out extensively, particularly in western United States, e.g., Lesperance and Bohman (1961) and Connor et al. (1963) in Nevada; Van Dyne and Meyer (1964) and Wilson et al. (1974) in California; Handl and Rittenhouse (1972) and Kartchner (1975) in Oregon; Jefferies and Rice (1969) in Wyoming; Scales (1972) in Colorado; Rittenhouse et al. (1970) and Lake et al. (1974) in Nebraska; Erwin et al. (1959) in Arizona; and Cordova (1977) in New Mexico. Fecal collections with grazing animals in other geographical areas have been carried out by Holmes et al. (1961) and Minson and Kemp (1961) in England; Lancaster (1954) and Kennedy et al. (1959) in New Zealand; Arnold et al. (1964), Donelly et al. (1974), and Moran (1976) in Australia; Elliot and Fokkema (1961) in Rhodesia; and Oyenuga and Olubajo (1975) in Nigeria.

Since much time and care is spent collecting feces, the method is generally regarded as expensive, time consuming, and impractical under some situations (Corbett 1960; Brisson 1960). In a somewhat subjective way, Kartchner (1975) estimated that about 70 man-hours of field work were needed to obtain each individual fecal output measurement. This did not include preliminary preparations or sample conditioning for analysis. This figure seems high, but is logical if all details of the method are considered. Besides constant changing, weighing, and cleaning of fecal bags, other problems frequently arise. e.g., supervision and rearranging of harnesses to prevent fecal loss (Van Dyne 1969).

A negative feature related to fecal collection apparatus is its possible adverse effect on animal physiology. Such equipment has reportedly caused reductions in live weight gains, although herbage intake and digestibility were not affected (Hutchinson 1956). Brisson (1960) reported that this method precluded studies over long periods, but that statement has been contradicted by many grazing and "conventional" digestion trials in which animals have been bagged for long durations. Greenhalgh et al. (1960) bagged steers for at least 50 days and indicated they showed no discomfort, and Raymond et al. (1953) bagged sheep for 150 days with no adverse effects. Lesperance and Bohman (1961) found no problems with fecal and urine collection apparatus used under a variety of conditions in Nevada, which included 32 collections in drylot, 32 collections on improved pastures, and 17 collections on semi-desert, sagebrush ranges.

Price et al. (1964) and Phar et al. (1971) found no significant differences in individual feed consumption, nor body weight gains, between bagged and nonbagged animals. In the 1971 study, with confined 2-year-old steers, collections were made continuously for 6 days with DMI being 12.9 and 13.8 kg for the bagged and "intact" animals, respectively. Likewise, other studies have reported that harnesses did not interfere with growth and normal behavior during either indoor or field experiments. Ingleton (1971) harnessed lambs at 1 or 2 days of age until they were 6 months old and found harnessing did not interfere with normal growth in the early stages when the greatest effect might have been expected.

In view of objections raised against other methods for estimating fecal output, and eventually intake, it may be concluded that total collection may still be the procedure of choice under many situations, in spite of its relatively arduous and time consuming disadvantages.

Animal Variability and Numbers Required for Sampling

One of the major factors affecting precision of intake measurements is its high individual variability, even when expressed in metabolic units (Van Dyne and Meyer 1964; Minson and Milford 1968). The average between-animal coefficient of variation (CV) of intake by sheep has generally ranged between 10 and 16% (Blaxter et al. 1961; Minson et al 1964; Heaney et al. 1968). Almost no data are available regarding intake variability in cattle, but sheep are reportedly three to four times more variable than cattle (Van Dyne and Meyer 1964).

A direct consequence of the high variability associated with intake measurements is that, to evaluate pastures or forages, large numbers of animals must be used to detect significant differences between treatments. This was illustrated by Heaney et al. (1968) using data involving 2,427 individual sheep/period measurements which showed high individual variability, with an average CV of 16% and a mean standard deviation (SD) of 9.7 intake-units. The latter data agree closely with those obtained in other experiments. Crampton et al. (1960) and Blaxter et al. (1961) both reported a CV of 13% when three forages of varying quality were fed to five sheep. Minson et al. (1964) found a lower CV (10.5%) when several pure grass swards cut at several stages of maturity were fed to sheep. Deviations from these general averages appear in data given by Pfander (1970), who showed data with a CV of 26% for the intake of 14 forage diets, and by Butterworth (1965), who found a CV of about 7%

Several workers have shown that more animals are required for studying intake than are needed for other parameters. Obioha et al. (1970) and Lake and Clanton (1972) have shown that about three animals using 3 to 5 days of sampling would be enough for estimating forage nitrogen and digestibility. Scales (1972), however, showed that about 51, 15, and 7 steers would be needed to estimate intake within 5, 10 and 15% of a mean difference at a significant level ($P < .05$). Based on an average daily intake over 25 days for sheep and 9 days for cattle, Van Dyne and Meyer (1964) reported that about 16 sheep and two cattle would estimate intake in drylot within 10% of the mean and 90% confidence; but under grazing conditions about 26 sheep and eight steers would be needed to estimate intake with the same accuracy.

A similar phenomenon has been observed when measuring fecal output, since intake may be estimated from the ratio: fecal weight/indigestibility. Variation in intake measurements may result from differences in (1) dietary composition, (2) excretion rate, and (3) fecal composition (Van Dyne 1969). Generally there is little difference in dietary chemical composition from day to day within short periods under range conditions (Van Dyne and Heady 1965), and digestibility of intake is relatively uniform (Van Dyne 1969). Thus, variations in excretion rate and fecal composition become especially important in assessing estimates of intake under range conditions. If chemical composition of output is assumed constant, then variation in excretion rate may be considered as the main determinant of errors (Blaxter et al. 1956). Besides analytical and sampling errors, other errors caused by irregularity in excretion rate are inversely proportional to length of fecal collection period. These errors decrease rapidly as the period is lengthened (Blaxter et al. 1956).

Based on a 7-day preliminary period followed by 7 days of collection, Van Dyne (1969) considered about five steers per treatment necessary to estimate fecal output within 10% of the mean with 95% confidence. Scales (1972), sampling with six steers for six consecutive days, concluded that a minimum of six steers was required to estimate fecal excretion within 15% of the mean. Clanton (1961) found that the number of days needed to provide minimal variation in total fecal collection was about six or seven. Based on this review, more attention should be given to measurements of intake by using and combining new and different approaches, because cost and animal management problems usually make large numbers of animals impractical.

Intake Levels Measured in Grazing Livestock

According to Moore and Mott (1973), most intake trials measure differences in "relative consumption potential" (Welch and Smith 1969), or "potential intake" (Monson et al. 1972), but do not give absolute intake values. Therefore, intake values are not absolute but only indicative of relative differences in potential intake, and these differences perhaps have significance for forages only within a given experiment.

Crampton et al. (1960) suggested that a daily consumption of 80 g DM/MBW should be the intake of a "standard forage" by sheep. A comparable level in organic matter would be about 74 g OM/MBW when forage contains 8% ash (Moore and Mott 1973). In reviewing published intake data on 137 tropical forages by sheep, Jeffery and Holder (1971) concluded that the upper boundary for daily intake was about 83 g DM/MBW. Moore and Mott (1973) selected sheep intake data from hand-feeding experiments to illustrate maximum intake values as well as ranges (listing 29 examples for temperate grasses and 35 for tropical pastures). They showed that temperate grasses were consumed at levels between 30 and 94 g DM/MBW, with measurements frequently at 80 g DM/MBW or above. Tropical grasses had similar ranges (22 to 98) but levels of intake were

Table 2. Ranges in daily voluntary forage intake by grazing animals, expressed in grams per unit of metabolic body weight (MBW).

Reference	Location	Type of animal	Type of pasture	Intake (animal/day) originally expressed	grams/MBW	Basis of measure[a]
			Dry matter intake			
Cook & Harris, 1951	Utah	Sheep	Winter desert range	2.2 – 3.4 lb/100 lb	57.1–88.2	LR/TC
Fels et al., 1959	Australia	Sheep		1.4 lb/100 lb	36.3	
Elliott & Fokkema, 1961	Rhodesia	Africander cows	Summer veld grassland	1.5 – 1.9 lb/100 lb	38.9–49.3	LR/TC
Holmes et al., 1961	England	Cattle	Ryegrass-clover pastures	1.8 lb/100 lb	46.7	FN
Pearce & Vercoe, 1961	Australia	Sheep	Mature *Lolium rigidum*	1.7 lb/100 lb	44.1	FN
Cook et al., 1962	Utah	Sheep	Poor and good desert ranges	2.53–3.21 lb	65.7–83.3	LR
Connor et al., 1963	N. Nevada	Hereford steers	Sagebrush-grass range	8.4–10.4 lb	69.4–85.9	CR/TC
Connor et al., 1963	S. Nevada	Hereford steers	Desert shrub range	5.1 – 9.0 lb	42.1–74.4	CR/TC
Van Dyne & Meyer, 1964[b]	California	Sheep	Dry annual summer range	1.7 – 2.2 lb	43.5–58.0	LR/TC
Van Dyne & Meyer, 1964	California	2-yr steers	Dry annual summer range	10.6–13.1 lb	64.0–78.2	LR/TC
Streeter et al., 1968	Nebraska	Hereford steers	Sandhill range (1964)	1.8 – 2.5 lb/100 lb	48.0–64.9	LR/CrO
Streeter et al., 1968	Nebraska	Hereford steers	Sandhill range (1965)	1.4–1.7 lb/100 lb	37.6–44.1	LR/CrO
Smith et al., 1968	S. Nevada	Mature steers	Desert shrub range	5.3–10.2 kg	46.7–89.8	LR/CrO
Hyder et al., 1968	Colorado	Hereford steers	Summer blue grama range	16.5–33.5 lb	135.6-204.2	Water/int.
Jefferies & Rice, 1969	Wyoming	Hereford steers	Shortgrass range (1966)	1.7–2.8 kg/100 kg	53.8–88.5	IVDMD/TC
Jefferies & Rice, 1969	Wyoming	Hereford steers	Shortgrass range (1967)	1.9 – 2.4 kg/100 kg	60.1–75.9	IVDMD/TC
Rittenhouse et al., 1970	Nebraska	330-kg heifers	Winter sandhill range	50.0–58.0 g/MBW	50.0–58.0	LR/TC
Handl & Rittenhouse, 1972	Oregon	275-kg steers	Crested wheatgrass pasture	5.4–7.2 kg	80.0–108.1	IVDMD/TC
Scales, 1972	Colorado	Hereford steers	Sandhill range (May to Nov)	2.9–6.1 kg	41.3–86.6	IVDMD/TC
Streeter et al., 1974	Colorado	Mature Hereford cows	Native meadow forage	9.5–11.8 kg	97 –121[c]	IVCWC/CrO
Lake et al., 1974	Nebraska	Yearling steers	Irrigated pastures	7.97 kg	116.1	IVDMD/TC
Orcasberro, 1974	New Mexico	Sheep	Irrigated alfalfa	1.0 lb/100 lb	26.0	LR/TC
Kartchner, 1975	Oregon	Lactating cows	Crested wheatgrass pasture	8.2–17.9 kg	75 –145[c]	IVDMD/TC
			Organic matter intake			
Arnold et al., 1964	Australia	Sheep	Perennial and annual pastures (diff. stocking rates)	0.62–1.42 kg	39.7–78.3	FN/TC
Arnold & Dudzinski, 1967	Australia	Ewes (diff. physiol. status)	*Phalaris* and *Trifolium* pastures	0.87–1.96 kg	48.5–109.2	VN/CrO
Hills, 1968	New Mexico	Hereford and Sta. Gertrudis cows	Semidesert grassland	7.2–14.5 kg	75.4-151.1	LR/CrO
Scales, 1972	Colorado	Hereford steers	Sandhill range	36.7–75.7 g/MBW	36.7–75.7	IVOMD/TC
Langlands & Bowles, 1974	Australia	Sheep	Native pastures	0.95–1.25 kg	63.3–78.6	IVOMD/CrO
Donnely et al., 1974	Australia	3-yr sheep (33 kg)	*Trifolium* pastures	0.65–0.92 kg	49.8–70.5	IVOMD/TC
Oyenuga & Olubajo, 1975	Nigeria	260-kg steers	Tropical-pasture mixtures	4.44–8.18 kg	82.3–95.2	FN/Cro
			Digestible organic matter intake			
Langlands, 1968	Australia	Sheep (different ages and breeds)	Improved pastures	0.62–1.11 kg	39.3–52.4	FN/CrO
Wilson et al., 1971	California	Sheep	Native annual grassland	0.93–1.10 kg	53.2–62.9[c]	IVCWC/TC
Wilson et al., 1971	California	Sheep	Improved annual and native grasses	0.74–1.04 kg	42.3–59.5[c]	IVCWC/TC
Scales, 1972	Colorado	Hereford steers	Sandhill blue grama range	23.1–46.2 g/MBW	23.1–46.2	IVOMD/TC
Langlands & Bowles, 1974	Australia	Sheep	Native pastures	0.50–0.70 kg	31.4–46.7	IVOMD/CrO
Young & Newton, 1974	England	Lactating sheep (diff. breeds)	Perennial ryegrass	0.50–2.12 kg	24.3–94.5	IVOMD/CrO
Oyenuga & Olubajo, 1975	Nigeria	260-kg steers	Tropical-pasture mixtures	2.85–5.54 kg	52.3–64.5	FN/CrO
Arnold, 1975	Australia	Sheep (diff. breeds)	*Phalaris* and *Trifolium* pastures	0.60–0.98 kg	34.3–56.1	FN/TC
Bishop et al., 1975	Argentina	2-yr-old wethers	Semiarid sandhill grassland	6.7–13.2 g/kg W	17.5–34.7	IVOMD/TC
Moran, 1976	Australia	Brahman cattle	Improved pastures	1.95–5.80 kg	31.2–83.2	FN/CrO
Moran, 1976	Australia	Hereford cattle	Improved pastures	2.40–6.80 kg	42.7-101.7	FN/CrO

[a] LR=lignin ratio; TC=total collection; FN=fecal nitrogen; Cr=chromogen ratio; CrO=chromic oxide ratio; IVDMD or IVOMD=in vitro digestibility; CWC=cell wall constituents.
[b] Van Dyne and Meyer (1964) also used silica and cellulose microdigestion for estimating intake.
[c] Approximated values because no body weights are given.

above 80 g DM/MBW less frequently than those for temperate grasses (Moore and Mott 1973). Intake values for 14 forage diets selected by Pfander (1970) agree closely with the former reports as he obtained a range between 51 and 119, with a mean OMI of 75.9 g/MBW.

Compared to hand-fed forages, intake data for grazing animals is quite limited (Table 2). Since intake values were expressed in varying terminology, particularly those by American workers, an effort was made to convert them to metabolic units. Recognition is made that intake was not always expressed as a function of body weight probably because different physiological status of animals within a given experiement produced no meaningful relationships between intake and body size (Young and Newton 1974; Arnold 1975).

Most intake estimates for grazing livestock appear to vary more with techniques used and researchers involved than with forages and environmental conditions tested. Dry matter intake by cattle grazing sandhill pastures in Nebraska during 1964 ranged from 48 to 65 g/MBW, whereas in 1965, a year of higher precipitation, DMI varied from 37 to 44 g/MBW (Streeter et al. 1968). The lower intake in 1965 was attributed to increased moisture content of forage consumed; however, according to Lake et al. (1974), the amount of water ingested with grasses does not affect intake. Rittenhouse et al. (1970) reported intake values ranging from 50 to 58 g/MBW for winter pastures in the same location. Using similar pastures in Colorado, Scales (1972) found an average DMI by cattle of 63 g/MBW and a range of 41 to 87 g/MBW, although the lowest value was estimated during November, while the lowest values reported by Streeter et al. (1968) were in June and August, for 1964 and 1965, respectively. Since Rittenhouse et al. (1970) and Streeter al. (1968) used the lignin-ratio method for estimating digestibility, the technique may have worked differently on pastures at different stages of maturity. Wallace and Van Dyne (1970) demonstrated that lignin digestibility varies with types of pasture and degree of plant maturity, whereas others have shown both erratic and unrealistic digestibility values when the lignin-ratio technique has been used on forages containing 5% or less lignin (Scales et al. 1974).

Cattle grazing Western United States ranges usually consume quantities of forage dry matter ranging from 1 to 3% of body weight (Table 2). Some actual values were 0.9 to 2.2% in Nevada (Connor et al. 1963); 1.4 to 2.6% in Nebraska (Rittenhouse et al. 1970; Lake et al. 1974); 1.0 to 2.4% in Colorado (Scales 1972); 1.6 to 3.6% in Oregon (Handl and Rittenhouse 1972; Kartchner 1975); and 1.7 to 2.8% in Wyoming (Jefferies and Rice 1969). A high estimation of intake was reported by Hyder et al. (1968), using the water-intake method to calculate forage intake ranging from 16.5 to 33.5 lb/day for 463- to 690-lb yearling Hereford steers, respectively. This represents an intake figure ranging from 7.5 to 15.2 kg DM/day, which is 3.6 to 4.9% of body weight, or 135 to 204 g/DM/MBW.

Intake estimates for grazing cattle in the United States are comparable to those of Elliot and Fokkema (1961), who found Africander and Mashona cows grazed, respectively, 1.9 and 1.5% body weight from summer Veld grassland in Rhodesia. Oyenuga and Olubajo (1975) found intakes of 2.3% in 1967 and 2.5% in 1968 for tropical pasture mixtures in Nigeria; whereas, Holmes et al. (1961) estimated DMI by cows to be about 1.8% on pastures in England.

Effect of Plant Maturity

In general, both intake and digestibility of a given plant species decline with advancing maturity. It is possible, however that a good correlation between intake and digestibility as plants mature may be coincidental rather than a cause-and-effect relationship. Moore and Mott (1973) prepared an extensive list of comparisons between intake and digestibility and showed that within species, correlation coefficients of 0.9 or better were observed only by Minson (1972). In most other cases, correlation coefficients were too low to suggest that digestibility per se is the only or even the primary factor controlling forage intake.

Variation of forage intake with increasing maturity is probably highly species-oriented. In most cases intake decreases with plant growth, but rate of decline has not been consistent. Furthermore, with some plant species, intake remained fairly constant over a considerable period, e.g., Milford and Minson (1968) noticed that intake of Rhodes grass remained constant up to 170 days. Similarly, DMI of *Phaseolus atropurpureus* var. *Siratro* remained at a very high level up to 260 days, at which stage the foliage was completely dead (Milford and Minson 1965). Heaney et al. (1966) found that S-50 timothy had a constant intake over a wide range of maturity. However, it should be noted that all these data were obtained from indoor feeding experiments and may not necessarily be applicable to grazing conditions.

Limited data have been published regarding changes in DMI with advancing maturity under grazing conditions. There is, however, considerable evidence that intake decreases as the grazing season progresses. Only in one of nine experiments reviewed, i.e., Streeter et al. (1968), were irregular patterns in forage consumption found which could not be explained in terms of plant maturity. In most other trials, intake reached a peak with the new growth, after the rainy season started, and declined thereafter. More detailed observations on changes in forage intake with advancing maturity are listed in Table 3.

Effect of Nitrogen Fertilization

Evidence for the influence of fertilization on forage intak ruminants is meager. Mahoney and Poulton (1962) observed no differences in intake by sheep of timothy fertilized at 45 or at 134 kg of N/ha. Holmes and Lang (1963) found that intake by steers was the same on grass fertilized with either high or low levels of nitrogen. Reid and Jung (1965) noted that fertilization of tall fescue had no effect on DMI by sheep and later Reid et al. (1966) reported that neither level nor source of N fertilizer had a significant effect on level of orchardgrass intake by sheep. On the other hand, Odhuba et al. (1965) noted a significant increase in the intake by sheep grazing tall fescue fertilized with high levels of N. Similar results were found by Kelsey et al. (1973) with sheep fed blue grama hay. Higher responses to N fertilization have been found in topical pastures, where intake was increased as much as 78% (Minson 1973). The most likely reason for this difference in response was the low levels of less than 1% N in control diets.

Summary

Present methods for estimating intake by grazing livestock lack precision and are often tedious, expensive, and time consuming. In this respect, some techniques may be superior to others, but many appear to yield results which may be seriously biased. The modern use of multiple regression analysis and computational capabilities for obtaining prediction equations may increase the possibility of obtaining more precise estimates of forage intake. However, such predictive functions cannot be

Table 3. Changes in forage intake with advancing maturity in pastures grazed by esophageal-fistulated animals.

Reference	Location	Vegetation type	Sampling dates	Daily intake	Units/day	Basis of measure[a]
Connor et al., 1963	Nevada (N)	Sagebrush-grassland	Jun, Jul, Aug 1960	4.7 3.8 3.9	kg DM	CR/TC 1
Connor et al., 1963	Nevada (S)	Desert shrub range	Jul, Aug, Sep 1960	3.3 4.1 2.3	kg DM	CR/TC 1
Van Dyne and Myer, 1964	California	Annual dry foothill	Jul, Aug, Sep 1961	6.2 5.8 6.1	kg DM	NB/TC 1
Van Dyne and Meyer, 1964	California	Annual dry foothill	Jul, Aug, Sep 1961	0.9 1.0 0.9	kg DM	NB/TC 3
Streeter et al., 1968	Nebraska	Sandhill native range	6/9, 6/21, 7/3 7/21, 8/11, 9/11, 1964	1.9 1.8 1.9 2.1 2.2 2.5	kg DM/ 100 kg	LR/CrO 1
Streeter et al., 1968	Nebraska	Sandhill native range	6/9, 6/22, 7/8 7/28, 8/24, 1965	1.5 1.6 1.7 1.6 1.7	kg DM/ 100 kg	LR/CrO 1
Wilson et al., 1971	California	Native annual grasses	Apr, Jun, Aug 1968	1.1 0.9 1.0	kg DOM	IVC/TC 3
Wilson et al., 1971	California	Improved annual pastures	Apr, Jun, Aug 1968	0.9 0.7 1.0	kg DOM	IVC/TC 3
Scales, 1972	Colorado	Sandhill blue grama	5/1, 5/26, 6/22, 7/23, 9/1, 11/2, 1970	49.7 63.6 58.7 75.7 54.4 36.7	g OM/W .75	IVD/CDT 1
Langlands and Bowles, 1974	Australia	Native pastures	Jan (NG), May, Aug (M), Oct (NG)	1.1 1.1 1.0 1.2	kg OM	IVD/CrO 3
Streeter et al., 1974	Colorado	Native mountain meadow	6/16, 7/26, 9/8, 10/18, 1970	11.8 10.2 9.5 9.8	kg DM	IVD/CrO 2
Kartchner, 1975	Oregon	Crested wheatgrass	4/29, 5/20, 6/10, 7/29, 1974	12.4 16.5 10.0 9.0	kg DM	IVD/TC 2
Bishop et al., 1975	Argentina	Semiarid native sandhill grassland	Jan to Dec 1968	9.7 12.7 13.2 8.5 10.3 8.6 6.7 8.7 9.5 k9.0 9.8 10.6	g DOM/W .75	IVD/TC 3
Smith et al., 1968	Nevada (N)	Desert shrub range	Jan, Jun, Sep	5.3 7.4 10.2	kg DM	LR/CrO 1
Handl and Rittenhouse, 1972	Oregon	Crested wheatgrass	Apr/70, Jun/70, Apr/71	7.2 6.7 6.5	kg DM	IVD/TC1

[a] Basis of measurement: X/Y; X=digestibility est.; Y=fecal output est.; CR=Chromogen ratio; LR=Lignin ratio; NB=Nylon bag; TC=Total fecal collction; IVD=Digestibility in vitro; IVC=in vitro cell walls; CDT=continuous dig. trial; M=Mature; NG=New growth; 1=steers; 2=cows; 3=sheep.

applied under all circumstances. Irrespective of the technique used, investigators must verify or determine, under their experimental conditions, the proper predictive function to be used.

The trend in expressing intake estimates with grazing livestock is in terms of g/DM or OM/$W_{kg}^{.75}$ although some researchers prefer simpler forms. Among methods used to estimate intake it would appear that the most reliable data have been provided where fecal output was determined by total collection and digestibility measured by in vitro analysis of grazed forage samples. The fecal N method appears quite adequate for estimating digestibility under certain grazing conditions but has not proven very accurate in the direct estimation of intake by grazing animals. The lignin ratio method has very limited value in estimating digestibility and, consequently, intake under grazing conditions.

Intake estimates for grazing livestock have been highly variable but those considered most valid in this review showed a range of 40 to 90 g DM/$W_{kg}^{.75}$. From several studies conducted with grazing cattle and sheep in western United States, intake estimates have generally ranged from about 1 to 2.8% of body weight. Ranges found in both of the above cases were associated with a decline in intake with advancing plant maturity on grazing areas. The relationship between intake and forage maturity is apparently more variable than that between digestibility and forage maturity.

The effect of nitrogen fertilization on forage intake is inconsistent although large increases in intake have sometimes been observed particularly on tropical pastures.

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Diets of the Black-tailed Hare in Steppe Vegetation

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Highlight: Thirteen species of plants were identified in fecal pellets of black-tailed hares collected from sagebrush and bitterbrush communities in southcentral Washington. Microscopic analysis of plant fragments indicated that yarrow was the most common food item in the diet, making up 25% of the overall diet. Other food items in decreasing order of importance were: turpentine cymopterus > hoary aster > needleandthread > and Jim Hill mustard. Preference indices indicated that needleandthread was the most preferred plant in the sagebrush community, while yarrow was the most preferred plant in the bitterbrush community. Although the communities were not similar in plant species frequency of occurrence and cover, the hare diets were quite similar in both communities, indicating that hares were actively seeking preferred foods.

Black-tailed hares (jackrabbits), *Lepus californicus*, are important herbivores on rangelands throughout the central and western United States (Hall and Kelson 1959). On many rangelands they can compete for forage with livestock and other wildlife. Hansen and Flinders (1969) have reviewed the known dietary habits of hares in North America. The objective of this investigation was to determine the dietary habits of black-tailed hares within sagebrush (*Artemisia tridentata*) and bitterbrush (*Purshia tridentata*) communities in southcentral Washington. The communities are utilized to some extent by mule deer (*Odocoileus hemionus*) and small mammals such as the ground squirrel (*Spermophilus townsendi*) but have not been grazed by livestock since 1943.

Study Area and Methods

The study area is on the Department of Energy's Hanford Reservation in southcentral Washington, on a broad plain that slopes gently toward the Columbia River. This area is characterized by gently undulating topography and the soils are mainly Rupert sands and Burbank loamy sands (Hajek 1966). The elevation is about 223 m with an average annual precipitation of 16 cm (Stone et al. 1972). Daubenmire (1970) described the two plant communities as *Artemisia tridentata/Poa sandbergii* and *Purshia tridentata/Stipa comata* associations. Both plant communities have been invaded by introduced annuals, especially cheatgrass (*Bromus tectorum*), which has become the dominant understory herb (Cline et al. 1977). The sagebrush community occupies approximately 546 km^2, while the bitterbrush community encompasses about 220 km^2 of the Hanford Reservation south and west of the Columbia River.

Fecal pellets were collected from two replicated sites located at random within the sagebrush and bitterbrush communities. Within each replicate two parallel transects (1 m × 50 m) were spaced 60 m apart. Each transect was subdivided into two lengths, 1 to 25 m and 25 to 50 m. All pellets were collected from these two subdivisions and designated as separate samples. This procedure was repeated for all transects, making a total of four samples for each replicate. Fecal pellets were dried at 70°C for 48 hours and ground through a Wiley mill (1-mm screen) to insure thorough mixing. All field sampling was conducted during April 1974. A total of 6,712 pellets and 2,871 pellets were included in the analyses for sagebrush and bitterbrush habitats, respectively. These analyses included a mixture of recent and old pellets from all seasons, dating back over a 10-year period as shown by radioactive dating (O'Farrell and Gilbert 1975; Uresk et al. 1975).

Fifteen microscope slides were prepared for each of the four samples from each site after the fecal contents had been washed over a 0.1-mm screen (Sparks and Malechek 1968). Slides were prepared with Hertwig's solution and Hoyer's solution (Baumgartner and Martin 1939) and dried for approximately 72 hours at 60°C.

Identification of plant fragments was made by microscopic examination of epidermal cell characteristics of vegetation in fecal material. Reference plant material prepared from specimens identified and collected from the study areas was used for comparisons. Twenty microscope fields were examined on each slide and all recognizable fragments recorded (Rogers and Uresk 1974). Fifteen slides were examined for each sample. Frequency of occurrence was determined by dividing the number of microscope views in which a given species occurred by the total number of views × 100 (Curtis and McIntosh 1950).

Vegetational analyses included canopy cover provided by each species and frequency of occurrence. Two replicated sites were examined in each of the sagebrush and bitterbrush communities. Each replicate in the sagebrush community consisted of four parallel line transects 50 m long and 30 m apart while vegetational measurements were collected on two transects in the bitterbrush community. The canopy cover and frequency of occurrence methods of vegetational analysis developed by Daubenmire (1959) were used for herbaceous taxa. Canopy cover was estimated using the following cover-class categories: class 1 (1–5%), class 2 (6–15%), class 3 (16–25%), class 4 (26–50%), class 5 (51–75%), and class 6 (76–100%). Estimations were based on ocular examination of 50 (2 × 5 dm, 0.1 m^2) plots systematically spaced at 1-m intervals along each 50-m line transect. Canopy cover and frequency of occurrence values were summarized by line transects. All sampling was conducted in April which is the mid-growing season for the understory vegetation consisting primarily of winter and spring annuals.

The density of shrubs was determined by counting all shrubs rooted within a 10 × 50 m plot centrally located in each replicated study site.

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Each shrub was measured for long and short canopy diameter to determine canopy cover.

A nested factorial design was used for comparisons between plant communities and all statistical tests, unless otherwise noted, followed Snedecor and Cochran (1967).

Kulczynski's similarity indices (Oosting 1956) and Spearman's rank correlation coefficients (r_S) (Siegel 1956) were calculated for diet and plant communities to determine the degree of associations.

Preference indices were calculated by dividing the relative frequency in the diet by relative frequency in the habitat. Plant and dietary data collected in the field as frequency of occurrence were converted to percent relative frequency by species or as a percent of the total frequency of all species. All values were rounded to the nearest 0.1. The preference indices as used here are regarded only as a guide to food preferences rather than absolute values. Other methods of evaluating forage preferences of herbivores are presented by Krueger (1972).

Results

Vegetational Analyses

A total of 21 and 28 plant species were identified in the bitterbrush and sagebrush communities, respectively (Table 1). Sixteen species were common to both associations. Cheatgrass was the most abundant herbaceous plant in both communities. The bitterbrush community had fewer plant species, especially in the forb category.

Grasses provided about 40% of the canopy cover in the bitterbrush community and about 21% in the sagebrush community (Table 1). Forbs provided 14% and 16% cover for the bitterbrush and sagebrush communities, respectively. The total understory cover provided by herbaceous species was approximately 17 percentage units higher in the bitterbrush vegetation than that associated with the sagebrush ($\alpha \leq 0.01$). If cheatgrass

Table 1. Frequency of occurrence (% ± SE) and canopy cover (% ± SE) of plants in April 1974 within two plant communities used by black-tailed hares.

	Frequency of Occurrence		Cover	
	Sagebrush[1] Community	Bitterbrush community	Sagebrush[1] community	Bitterbrush community
Grasses				
Needleandthread (*Stipa comata*)	0.3 ± 0.3	0.5 ± 0.5	<0.1	<0.1
Sandberg bluegrass (*Poa sandbergii*)	21.5 ± 4.2	36.5 ± 6.9	1.7 ± 0.5	5.2 ± 2.0**
Cheatgrass (*Bromus tectorum*)	94.0 ± 1.5	98.0 ± 1.5	15.3 ± 0.9	34.9 ± 0.9**
Fescue (*Festuca spp.*)[2]	75.0 ± 6.1	1.0 ± 0.6**	4.0 ± 0.7	<0.1 **
Total grasses			21.0	40.1
Forbs				
Yarrow (*Achillea millefolium*)	1.0 ± 1.0		<0.1	<0.1
Turpentine cymopterus (*Cymopterus terebinthinus*)	0.8 ± 0.4		0.3 ± 0.2	
Hoary aster (*Aster canescens*)	3.3 ± 3.3		0.2 ± 0.2	
Jim Hill mustard (*Sisymbrium altissimum*)	1.0 ± 1.0		<0.1	
Matted cryptantha (*Cryptantha circumscissa*)	49.3 ± 4.6	15.0 ± 4.4**	1.8 ± 0.2	0.4 ± 0.1**
Blazing star (*Mentzelia albicaulis*)	0.5 ± 0.5		<0.1	
Carey's balsamroot (*Balsamorhiza careyana*)	0.8 ± 0.5		0.2 ± 0.1	
Wing-nut cryptantha (*Cryptantha pterocarya*)	11.8 ± 3.1	6.0 ± 2.5	0.6 ± 0.1	0.2 ± 0.1*
Spring draba (*Draba verna*)		72.0 ± 5.4		3.8 ± 0.8
Tansy mustard (*Descurainia pinnata*)	84.5 ± 5.0	4.0 ± 2.8**	8.0 ± 1.0	0.2 ± 0.1**
Pink Microsteris (*Microsteris gracilis*)	65.0 ± 5.0	48.5 ± 6.1	3.2 ± 0.5	2.5 ± 0.4
Threadleaf phacelia (*Phacelia linearis*)	6.5 ± 3.5	0.5 ± 0.5	<0.1	<0.1
Wallflower (*Erysimum asperum*)	2.7 ± 1.2		0.2 ± 0.2	
Russian thistle (*Salsola kali*)	4.5 ± 2.1	1.0 ± 1.0	0.1 ± 0.1	<0.1
Fiddleneck (*Amsinckia lycopsoides*)	1.0 ± 0.7	2.5 ± 0.5	<0.1	<0.1
Phlox (*Phlox longifolia*)	3.7 ± 1.9		0.7 ± 0.3	
Scurf-pea (*Psoralea lanceolata*)	<0.1	<0.1	<0.1	<0.1
Buckwheat (*Eriogonum spp.*)	3.0 ± 1.4	16.0 ± 4.7**	0.4 ± 0.2	2.7 ± 1.7
Pale comandra (*Comandra pallida*)	0.5 ± 0.3		<0.1	
Evening-primrose (*Oenothera pallida*)	0.5 ± 0.3		<0.1	
Star tulip (*Calochortus macrocarpus*)	1.5 ± 0.8		<0.1	
Willow-weed (*Epilobium paniculatum*)	0.3 ± 0.3	8.0 ± 1.4**	<0.1	0.2 ± 0.1
Brodiaea (*Brodiaea douglasii*)	0.7 ± 0.7		<0.1	
Jagged chickweed (*Holosteum umbellatum*)		29.0 ± 9.8		3.5 ± 1.6
Lomatium (*Lomatium spp.*)		0.5 ± 0.5		<0.1
Total forbs			15.7	13.5
Total herbaceous cover			36.7	53.6
Shrubs				
Big sagebrush (*Artemisia tridentata*)	36.0 ± 3.9	5.5 ± 1.3**	33.4 ± 1.6	9.0 ± 1.5**
Bitterbrush (*Purshia tridentata*)		23.0 ± 3.7		29.5 ± 2.4
Rabbitbrush (*Chrysothamnus nauseosus*)		1.5 ± 0.5		3.5 ± 0.5
Green rabbitbrush (*Chrysothamnus viscidiflorus*)	0.5 ± 0.3	1.5 ± 0.9	<0.1	1.1 ± 0.3**
Total			33.4	43.1

[1] Sagebrush community, n=8 (Cline et al., 1977) Bitterbrush, n=4.
[2] Annual species.
* Significantly different from sagebrush community $a \leq 0.05$.
** Significantly different from sagebrush community $a \leq 0.01$.

were excluded from the total understory cover, both sites had approximately the same amount of cover.

Shrub cover averaged 33 and 43% in the sagebrush and bitterbrush communities, respectively (Table 1). The bitterbrush site had significantly ($\alpha \leq 0.01$) more total shrub cover than the sagebrush community, primarily due to the addition of sagebrush and rabbitbrush in the bitterbrush community. Bitterbrush has a different form than sagebrush, generally providing more cover per shrub. The average number of shrubs in the sagebrush site was 188/500 m^2 as compared to 90/500 m^2 in the bitterbrush community. Heights of sagebrush and bitterbrush were similar at both sites, averaging 85 and 88 cm, respectively. Rabbitbrush was much shorter in stature, ranging between 51 and 58 cm.

Pellet Composition

Thirteen plant species were identified in hare fecal pellets from both plant communities (Table 2). Yarrow was the most common species, comprising 48 and 71% frequency of occurrence in fecal samples from the bitterbrush and sagebrush sites, respectively. Needleandthread was the most common grass found in the diets. However, Sandberg bluegrass was abundant in diets from the bitterbrush area. Forbs provided the mainstay of the hare diets and were found approximately 22% more frequently in pellets from the sagebrush site. Rabbitbrush occurred more frequently in fecal pellets from the bitterbrush area. Although sagebrush also occurred in the bitterbrush site, it was only found in the pellets from the sagebrush community. The average composition of plant species in the hare fecal pellets based upon relative frequency consisted of 75% forbs, 14% grasses, 9% shrubs, and 1% unidentifiable material in the sagebrush community. Plant composition of fecal pellets in the bitterbrush community consisted of 69% forbs, 20% grasses, 10% shrubs, and 1% unidentifiable material.

When a plant species is scarce in the habitat but shows up frequently in the fecal pellets, it is assumed that this particular plant is actively sought by the foraging animal (Table 3). Needleandthread grass was the most highly preferred species in the sagebrush community. Other highly preferred forage plants in decreasing order include yarrow, turpentine cymopterus, Jim Hill mustard, rabbitbrush and hoary aster. Yarrow was the most highly preferred species in the bitterbrush community. Other highly sought after species in decreasing order include turpentine cymopterus, hoary aster, needleandthread, Jim Hill mustard, scurf-pea, and rabbitbrush. The hares were more actively seeking specific forage plants in the bitterbrush area than in the sagebrush community. This is reflected in the average preference indices of 104 and 63 of the respective communities. Cheatgrass was the most abundant plant in both study sites but did not appear in the fecal pellets, indicating that hares were selecting against this species.

The hare diets and preference indices were significantly more similar between plant communities than the vegetation when examining frequency and cover (Table 4). These data indicate that the hares are generally selecting for the same plants within both plant communities, although the communities are not necessarily similar in regard to frequency and cover values.

Table 2. Average botanical composition (%±SE) of fecal pellets collected from black-tailed hares.

Category	Sagebrush community[1]	Bitterbrush community[1]
Grasses		
Needleandthread	36.6 ± 2.3	28.9 ± 4.2
Sandberg bluegrass	0.4 ± 0.4	15.4 ± 1.2**
Forbs		
Yarrow	71.0 ± 2.6	48.1 ± 2.6**
Turpentine cymopterus	42.1 ± 3.3	40.4 ± 1.8
Hoary aster	35.8 ± 2.2	38.0 ± 2.2
Jim Hill mustard	33.8 ± 3.0	14.6 ± 2.6**
Matted cryptantha	11.4 ± 3.1	3.8 ± 1.5*
Scurf-pea	1.6 ± 0.9	7.1 ± 1.7**
Carey's balsamroot		0.3 ± 0.3
Wing-nut cryptantha		0.6 ± 0.5
Spring draba	0.4 ± 0.4	
Shrubs		
Big sagebrush	9.6 ± 0.9	
Rabbitbrush	13.0 ± 2.8	20.9 ± 3.4*
Unknowns	2.5 ± 0.3	1.8 ± 0.5

[1] Frequency of occurrence values, n = 8.
* Significantly different from sagebrush community $a \leq 0.05$.
** Significantly different from sagebrush community $a \leq 0.01$.

Table 3. Preference indices of black-tailed hares by food items within two plant communities.

Plant taxa	Sagebrush community[1]	Bitterbrush community
Grasses		
Needleandthread	142	131
Sandberg bluegrass	<1	<1
Forbs		
Yarrow	137	219
Turpentine cymopterus	82	184
Hoary aster	20	173
Jim Hill mustard	66	66
Matted cryptantha	<1	<1
Scurf-pea	6	32
Carey's balsamroot		1
Wing-nut cryptantha		<1
Draba	2	
Shrubs		
Big sagebrush	<1	
Rabbitbrush	50	24
Average	63	104

[1] Preference index values were calculated as: (relative frequency of a species in the diet ÷ relative frequency of the same species in the community).

Discussion

Selectivity in foraging by the black-tailed hare has been reported by several investigators and is influenced by the phenological stages of plant growth (Hayden 1966; Sparks 1968; Hansen and Flinders 1969; Flinders 1971; and Flinders and Hansen 1972). Grasses were important food items during

Table 4. Average similarity indices (%) and rank-order correlation coefficients (r_s) of hare diets, preference indices (PI), frequency of occurrence and cover when comparing the two plant communities.

	Sagebrush community vs bitterbrush community	
Category	%	r_s
Diets	48	0.80**
PI	44	0.77**
Frequency	21	0.20
Cover	18	0.04

** Significant at $\alpha < 0.01$.

early spring and summer, while forbs were important during the summer and shrubs important in winter (Hayden 1966; Sparks 1968). Hares exhibited a preference for green succulent plants at all seasons. Selectivity may also be influenced by the amount of available energy stored in certain plants (Church et al. 1972).

Stewart and Hull (1949) maintain that hares strongly influence the development and maintenance of cheatgrass cover. Hares feeding heavily on perennial grasses prevented these grasses from invading cheatgrass communities. On areas where hares were purposefully excluded, perennial grass increased as rapidly as cheatgrass, but perennial grasses disappeared when grazed by both hares and cattle. Hares sometimes girdle main stems of sagebrush and rabbitbrush, and may thus destroy the plant.

Although hares were not especially abundant in these study areas, it does seem possible their selective feeding habits could be influential in keeping perennial grasses such as needleandthread from increasing in abundance in the absence of livestock grazing. Mule deer are the only big game animal known to graze this area during the past 30 years, and they generally concentrate in the bitterbrush community during the winter months. Deer densities are estimated at approximately .23/km^2 on the Hanford Reservation south and west of the Columbia River and their influence on the plant communities has been slight (Uresk, unpublished data).

The rank-order correlation coefficients for the food items found in the fecal pellets of the hares and preference indices were significantly correlated when comparing both plant communities. This indicates that hares are selecting and preferring the same food items at both sites. Preference indices of food items selected by the hares were high. Seven plants were highly preferred and sought out in much greater quantities relative to their percent frequency in the communities. The low similarity indices and nonsignificant correlation coefficients show that the plant communities are not related when considering frequency of occurrence and canopy cover of plants. Thus, the hares are actively seeking out certain food items they prefer.

The sagebrush and bitterbrush communities today are much like those that existed prior to 1943, when the Hanford Reservation was established (Cline et al. 1977). The major change in plant species composition has been the introduction of cheatgrass, which has been important to this area for more than half century (St. John and Jones 1928).

There is a need for additional dietary information concerning other important herbivores within the confines of the Hanford Reservation and other large nuclear facilities. Dietary analyses of the black-tailed hare and other herbivores when related to availability of forage plants in the habitats would provide information useful in selecting plants to revegetate shallow burial sites for low-level radioactive wastes from nuclear energy facilities. It is especially important to select plants not consumed by herbivores that have the ability to be self-maintained, yet prevent soil erosion. It is also important to select plants for revegetation that are not preferentially selected by wild herbivores because it is prudent to keep food chain transfers of radionuclides to a level low as possible.

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Plant and Soil Water Potentials Following Fire in a Northern Mixed Grassland

R.E. REDMANN

Highlight: Leaf water potential, osmotic potential, and soil moisture were measured in mixed grassland during the growing season following an October fire. Plant and soil water stress increased near the end of the May-August period in both burned and control sites. Potentials in nothern wheatgrass and junegrass become lower in burned than in control plots as the growing season progressed. Increased plant water stress was judged sufficient to account for the reductions in productivity which have been observed after fire.

The extensive literature describing the effects of fire on grassland composition and productivity has been reviewed by Daubenmire (1968) and Vogl (1974). Some studies (e.g., McMurphy and Anderson 1963) have compared soil moisture content of burned and unburned plots; however, no information on plant water status has been found in the literature.

Fire is used as a management tool in many grasslands; accidental and naturally caused fires also are important. Rowe (1969) carried out a survey which suggested that lightning-caused fires are relatively common in the grasslands of south-western Saskatchewan. He estimated that one year in six has the combination of abundant grass fuel and weather conditions conducive to widespread fires in the region.

In 1969, lightning-caused fires burned parts of the Matador Field Station, site of an intensive ecosystem study under the Canadian International Biological Programme. An accidental fire in October, 1970, which burned several hectares of the Station, provided an opportunity to study the effect of burning on plant-soil water relationships. The objectives were to measure seasonal changes in the water status of two dominant grasses growing on the burned and unburned plots, and to relate plant water status to environmental conditions and plant productivity.

Experimental Area

The Matador Field Station is located 45 km north of Swift Current, Sask., Canada. The vegetation of the site is described as the *Agropyron-Koeleria* faciation of the mixed prairie assocation (Coupland et al. 1973). Dominant plant species include northern wheatgrass (*Agropyron dasystachyum*) and june (*Koeleria cristata*), which contribute 44% and 6.5% of the total plant biomass, respectively. At mid-growing season approximately three-fourths of the above-ground biomass consists of dead shoot material. The total amount of standing dead in this ungrazed sward can exceed 500 g m^{-2}. A detailed discussion of sward structure appears in Coupland et al. (1973).

The climate of the region is classified as Type VII 5 (VI) Arid, with Cold Season (Walter and Leith 1960). Annual precipitation averages 388 mm, approximately one-fourth of which comes as snowfall. One-third of the annual precipitation falls during June and July; late summer drought is typical. Mean air temperatures range from 19°C (July) to −13°C (January) with an annual mean of 3.3°C. Ripley (1973) discusses the climate of the Matador region.

The soils of the Station belong to the Sceptre Association, consisting mainly of chernozemic brown soils of heavy clay texture, developed on glaciolacustrine deposits (deJong and Stewart 1973). The topography is that of a very gently undulating plain, which is locally dissected by ravines.

An accidental fire in October, 1970, burned a strip, several hundred meters in width, across a homogeneous section of the Field Station before being extinguished. Sampling was done along the burned and unburned sides of the fire line.

Methods

Water potentials and osmotic potentials of northern wheatgrass and junegrass were determined at 14 h on 18-21 days between May 18 and August 19, 1971. The youngest fully emerged leaf blades were removed from shoots in the field and sealed in 5-cm^3 polypropylene chambers. Four replicates, each consisting of 3-4 blades were collected at each sampling time. Water potential of the leaf tissue in the chambers was measured using Spanner-type thermocouple psychrometers. At each sampling time ten additional leaf blades were placed in each of four 3-cm^3 plastic syringes for determination of osmotic potential. Freezing-point depression of sap expressed from the leaf tissue after freezing and thawing was determined using a Knauer cyroscopic osometer. Details of the psychrometer and freezing-point equipment and measurement procedures are described by Redmann (1976).

Soil moisture content in the 0-15 cm layer was determined gravimetrically. Soil matric potential was calculated from the gravimetric measurements using a desorption curve determination by de Jong and Stewart (1973) for the Matador soil type.

Results and Discussion

Water Status in Burned and Unburned Plots

Water potentials of northern wheatgrass and junegrass growing in both the control and burnd plots were about −15 and −20 bars during late May (Fig. 1). Values rose to around −10 bars during June and early July, after which a strong downward trend in water potential was observed. The lowest water potentials in northern wheatgrass and junegrass were −35 and −45 bars, respectively. Junegrass probably exhibited greater stress because its root system tends to be confined to the shallower soil layers (Coupland and Johnson 1965), which dry out earlier.

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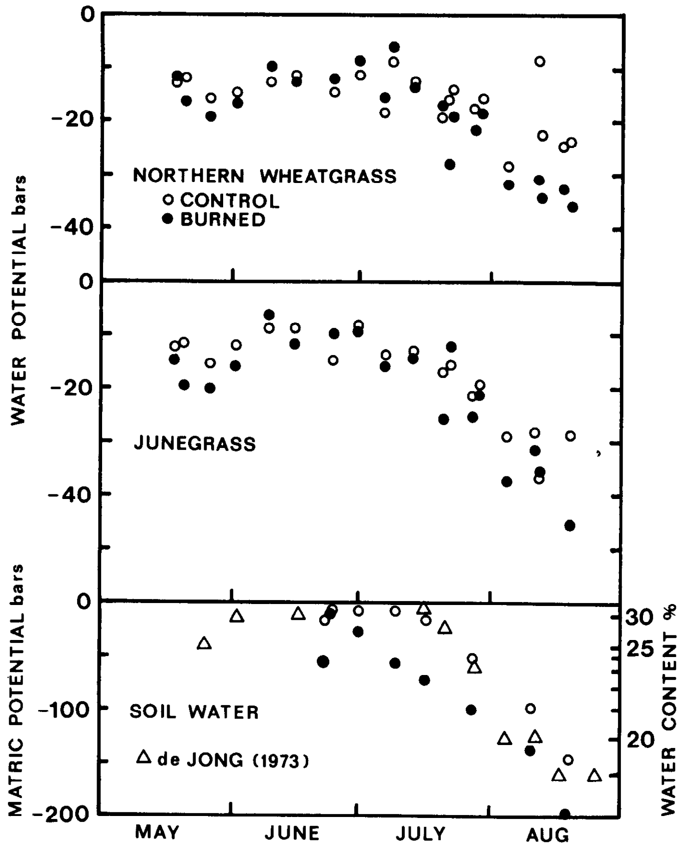

Fig. 1. *Seasonal patterns of plant water status in northern wheatgrass and junegrass and soil moisture (0-15 cm) in burned and unburned sites. Plots were burned the previous October. Each point is the mean of four replications; standard deviations for northern wheatgrass averaged 1.3 bars; for junegrass, 1.7 bars. Soil moisture measured in nearby unburned plots by de Jong (1973) is also shown.*

Water potentials and osmotic potentials of both species were significantly lower on burned than on control plots late in the growing season when potentials were lowest (Fig. 2). For example, when plant water potential of northern wheatgrass on the control plot was −25 bars, water potential in the burned area was significantly lower (−32.4 bars). When water and osmotic potentials of control plants were −15 bars, potentials on the burned site were not significantly lower (0.05 probability level, tested using procedures from Steel and Torrie 1960). Osmotic potentials of junegrass from burned plots were also significantly lower late in the growing season; water potentials were not significantly lower, even late in the season, because of the large variation at that time.

Regression lines of osmotic potentials and water potentials within the species were not significantly different (0.05 level). Water potential (WP) equalled osmotic potentials (OP) and since

$$WP = OP + TP,$$

turgor pressure (TP) was nil. Redmann (1976) found that turgor effects in northern wheatgrass were only important at water potentials above about −15 bars.

Causal Factors in Increased Stress on Burned Plots

Decreasing water potential over the season was related to soil moisture and precipitation patterns. Precipitation during August, 1971, was only 8% of the long-term average. Rainfall during the May-July period was about 88% of the 30-year mean. August was also hot: mean maximum air temperature was 5.6° above average.

Soil moisture content on the control plots dropped from about 35% in early July to 19% near the end of August (Fig. 1). Data

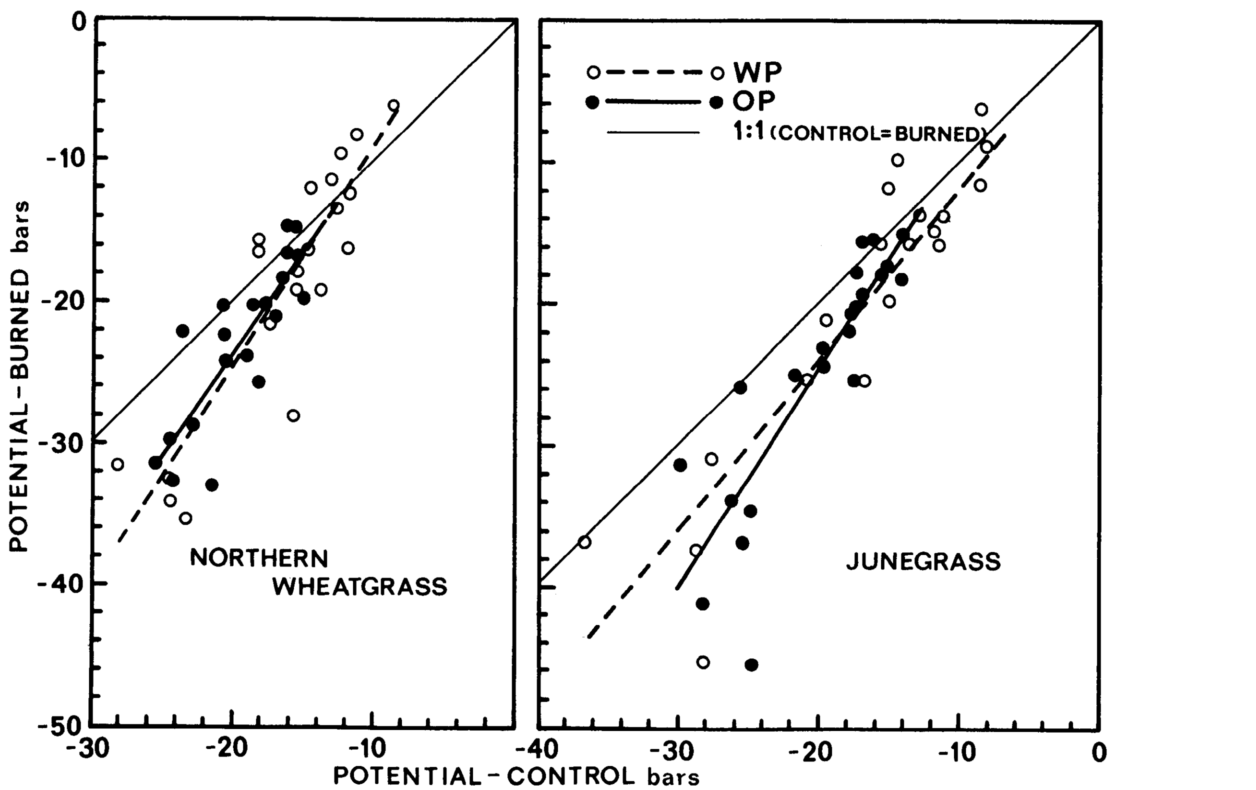

Fig. 2. *Relationships between water potentials (WP) and osmotic potentials (OP) of leaves of northern wheatgrass and junegrass from burned and unburned plots. Means of four replications were used in the linear regressions. Standard deviations for osmotic potentials of northern wheatgrass averaged 0.8 bars; for junegrass, 1.0 bars. All regressions were significant at the 0.01 level of probability.*

from deJong (1973), obtained on a nearby plot using a neutron probe, followed a similar pattern. Soil matric potentials on the control plot fell below −25 bars in late July; potentials in the burned plots were below −25 bars on every measurement date except one.

Soil matric potentials in the 0−15 cm layer were below plant water potentials measured during late July and August, indicating that lower portions of the soil profile must have been supplying water to the shoots. Water from deep in the profile is important for the survival of some shoot tissue during drought periods (Redmann 1976). Reduction in subsoil water would result in greater plant water stress, particularly during droughts, when deep moisture is of greater relative importance McMurphy and Anderson 1965).

Reasons for reduced soil moisture in the burned plots remain speculative. DeJong (1973) determined that soil moisture recharge in a Matador Station site burned in 1969 was reduced because of lack of standing dead vegetation which traps winter snow. The reduction in stored water in the profile to a depth of 150 cm was about 60 mm in May, which represented about 75% of the pecipitation coming as snow during the previous winter. Trlica and Schuster (1969) also reported less favorable spring soil moisture on fall-burned grassland because of reduced snow accumulation. Wight et al. (1975) measured greater snow depths and greater total snow cover on undisturbed native grassland compared to clipped plots. Other work has also documented the importance of snowtrapping in the Great Plains (Van Havern and Striffler 1968).

McMurphy and Anderson (1965) concluded that decreased infiltration rates, rather than reduced snow-trapping, explained lower soil moisture content on burned plots in eastern Kansas. Microclimatic changes resulting from fire also can influence plant and soil water relations (Daubenmire 1968).

Effect of Fire on Primary Production

Coupland (1974), studying a Matador Station site burned in August, 1969, found that peak green biomass the following season decreased by 28%, despite the fact that pecipitation was 43% above the long-term average. Daubenmire (1968) and Wright (1974) cite several references which showed reductions in forage production after fire. Greater water stress in plants growing on burned sites can explain reductions in primary production which have been observed. A change in plant water potential from −20 to −25 bars results in a decrease in photosynthesis of approximately 60% (Redmann 1973).

Fire in the semiarid grasslands appears to have a detrimental effect on plant productivity, as opposed to the beneficial effect reported in the more humid grasslands farther east (Vogl 1974). These detrimental effects can be traced to the influence of burning on snow hydrology, soil moisture, and ultimately, plant water status.

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Prescribed Burning of a *Festuca-Stipa* Grassland

ARTHUR W. BAILEY AND MURRAY L. ANDERSON

Highlight: The *Festuca-Stipa* grassland community was found to be well adapted to surviving a single prescribed burn. Coverage of rough fescue was reduced from one to three growing seasons after fire depending upon season burned and stage of growth. Spring burning benefited the production of seed heads in western porcupine grass but fall burning reduced its cover and production of seed heads. Annual herbage production was neither increased nor decreased if burning occurred when plants were dormant. Species composition shifted in favour of perennial forbs for at least 3 years after a burn.

Fire was an important ecological factor on Canadian prairie rangelands prior to white settlement. Fire frequency increased during the 1880 to 1920 era of settlement and railroad building (Moss 1932; Nelson and England 1971). Fires were considered such a hazard in the late 1800's that they had an important influence on the development of legislation and local government (Nelson and England 1971). The suppression of fire was so successful that these grasslands have existed without frequent fire for about 70 years.

The fescue grasslands of central Alberta and Saskatchewan are part of the aspen parkland. The degree of dominance of rough fescue (*Festuca scabrella*)[1] varies with climate, soil, and grazing pressure. Rough fescue is the dominant in the black soil zone on the northern (moist) fringe of the aspen parkland (Coupland and Brayshaw 1953). This grassland is almost pure rough fescue but it has virtually disappeared because of either cultivation or tree encroachment. In most of the aspen parkland, the remaining grasslands are in the more arid dark brown soil zone where rough fescue is a codominant with western porcupine grass (*Stipa spartea* var. *curtiseta*).

Moss (1932) observed that burning had effectively stopped tree advance in the Alberta aspen parkland. He predicted that in the absence of fire, succession would soon produce a considerable extension of the aspen (*Populus tremuloides*) forest. The rate of brush encroachment into, and the elimination of, the rough fescue grassland has increased (Maini 1960; Johnston and Smoliak 1968; Bailey and Wroe 1974; Scheffler 1976). However, the effect of lack of fire on the remaining rough fescue-western porcupine grass community is unknown.

The purpose of this study was to determine the effect of spring and fall prescribed burning on species composition and productivity of the rough fescue-western porcupine grass community.

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[1] Nomenclature follows Moss (1959).

Methods

The study area was located at the University of Alberta Ranch in Section 4, Township 47, Range 11, west of the 4th meridian, 158 km southeast of Edmonton, Alberta. The topography was moderate to strongly rolling, known locally as knob and kettle topography. The dark brown and black chernozemic soils[2] have developed from glacial till and have a loam texture. Average annual precipitation was 36 cm with 20 cm occurring during the May to August growing season. The July and January mean temperatures were 17°C and −19°C, respectively. The study area had been lightly grazed for 10 years.

All prescribed burns were located within 100 m of one another on similar parent material, soils, relief, and vegetation. The burns were conducted on a 3-ha area on May 8, 1970, on a 5-ha area on October 3, 1970, and on a 20-ha area on May 11, 1971. The burns were set as headfires although certain parts of each area were burned by backfires. There were no replications.

Vegetation Measurements in the Spring 1970 Fire

Permanent plots were set out in the burned and unburned treatment areas. A distance of 2 m was left unsampled on each side of the fire line to remove the edge effect. The burned and unburned areas were marked off in 2-m wide transects. A 20 x 50 cm plot was randomly located and permanently marked in each 2-m segment of a transect. Canopy coverage of all plant species and density of seed heads of rough fescue and western porcupine grass were measured in July 1970, 1971, and 1972. Density of shrub stems was measured in each plot in August 1970, 1971, and 1972. Canopy coverage was estimated following the method of Daubenmire (1968b) using the following canopy coverage classes: (Class number, canopy cover range, class mid-point) Class 1: 0−1% (0.5); Class 2: 2−5% (3); Class 3: 6−25% (15); Class 4: 26−50% (37.5); Class 5: 51−75% (62.5); Class 6: 76−95% (85); Class 7: 96−100% (97.5).

Vegetation Measurements in the Fall, 1970, and Spring, 1971 Fires

Five 5m × 7m macroplots were randomly selected from a number of possible sites within each of the (a) unburned control, (b) the 5-ha fall 1970 burned, and (c) the 20-ha spring 1971 burned treatments. The control macroplots were randomly selected from similar unburned stands immediately surrounding the burns. Each macropolot was divided into meter-square microplots. A 20cm × 50 cm plot was randomly located in each microplot. Canopy coverage estimates were made in July, 1971, for all plant species following the method described above. Also measured was the density of seed heads of rough rescue and western procupine grass.

Total annual herbage production was measured in September, 1971, by randomly locating three 0.9-m² microplots in each macroplot. The herbage was clipped to ground level, oven dried, and weighed.

[2] The Canadian soil classification system is used (Clayton et al. 1977).

The canopy coverage values wee transformed using the inverse sine prior to the use of analyses of variance tests. Data reported in all tables have been returned to the original percentage scale.

Results

The weather conditions prior to and during burning are presented in Table 1. Burning was conducted when rough fescue growth was about 10 cm tall in Burn 1, 4 cm tall in Burn 3, and after the herbaceous vegetaion had dried in Burn 2. Little precipitation had fallen prior to each burn and seasonal drying weather had been experienced. All burns were conducted under dry conditions where the relative humidity was 25% or less and winds were moderate. However, gusts of wind ranging from an estimated 33 to 58 kph blew flaming firebrands from shrubs causing one spot fire in Burn 1 and four spot fires in Burn 3. Burn 2 went out of control because of inadequately prepared fire lines and suppression procedures.

Table 1. Weather conditions prior to and during the three prescribed burns.

Variable		Burn 1	Burn 2	Burn 3
Date of burn		May 3, 1970	Oct 3, 1970	May 11, 1971
Total precipitation during previous 30 days (cm)		0.4	1.8	0.3
Weather conditions during previous 7 days:				
Mean maximum temperature (°C)	Kinsella	19	22	18
Mean wind speed (kph)	Kinsella	19	16	19
Mean relative humidity (%)	Edmonton	44	44	34
Weather on day of burn:				
Maximum temperature (°C)	Kinsella	19	24	25
Mean wind speed (kph)	Kinsella	23	13	13
Mean relative humidity (%)	Edmonton	42	47	29
Weather during burn:				
Wind speed (kph)	Kinsella	35	15	13
	Edmonton	35	15	15
Maximum gust	Edmonton	55	15	42
Relative humidity (%) during the fire	Edmonton	25	25	19

[1] A steady wind was recorded during the fire

Total canopy coverage in the rough fescue-western porcupine grass community changed only slightly the first growing season after either a spring or fall burn (Table 2). The canopy coverage of grasses and grass-like species decreased while coverage of perennial forbs increased.

The canopy coverage of several species was lower in both burn treatments. Rough fescue coverage was 26% lower in the spring burn and 6% lower in the fall burn, while its seed head production declined only after the spring fire. The coverage and seed production of western porcupine grass was reduced by fall burning. Coverage of sedges (*Carex* spp.) was 19% lower in the spring 1971 burn treatment. Hooker's oatgrass (*Helictotrichon hookeri*) and fringed sage (*Artemisia frigida*) were reduced by both fall and spring burns. The coverage value of several forbs including prairie sage (*Artemisia ludoviciana*) increased after both fall and spring burn treatments. Blue bur (*Lappula redowski*) and wild strawberry (*Fragaria virginiana* var. *glauca*) were present in the two burn treatments but were absent from the control. There were no annual forbs.

Table 2. Canopy coverage (%), density of seed heads (culms/m²) and annual herbage production (kg/ha) in the unburned, fall burned, and spring burned treatments.

Category	Season Burned		
	Unburned (n = 175)	Fall (n = 175)	Spring (n = 175)
Vegetation class:			
All classes	280	282	265
Grasses and grass-likes	252	224	200
Perennial forbs	26	54	60
Shrubs	3	3	6
Species:			
Rough fescue-cover	84a[1]	79b	62c
- seed heads	34a	35a	1b
Western porucpine grass-cover	86a	79b	84a
- seed heads	48a	11b	48a
Hooker's oatgrass	18a	6b	1b
Pasture sage	3a	+b[2]	+b
Sedge	54a	55a	44b
Wheatgrass[3]	6	4	8
Milk vetch[4]	4	12	11
Three-flowered avens	1b	11a	10a
Yarrow	1b	2a	4a
Blue bur	0b	1a	+a
Prairie crocus	7	7	8
Number of species	41	38	37
Annual herbage production	1180a	1145a	1365a

[1] Values within each row followed by a common letter a,b, or c do not differ significantly ($P < 0.05$) using Duncan's multiple range test.
[2] Canopy coverage was 0.5% or less.
[3] Includes *Agropyron trachycaulum* and *A. subsecundum*.
[4] Includes *Astragalus agrestis*, *A. flexuosus*, and *A. striatus*.

Annual herbage production at the end of the 1971 growing season was not changed by spring of fall burning (Table 2).

In the 1970 spring burn, total canopy coverage was 19% lower than the control the first growing season after fire (Table 3). One and two years later, total canopy cover was 8% and 6% less, respectively, in the burned area. The first year after burning, grass and shrub coverage was less in the burned area while forb coverage was greater. All classes increased in coverage the second year. In the third year, forbs declined while shrubs, grasses and grass-likes increased. The species most detrimentally affected by spring burning were rough fescue, wheatgrasses, and the shrub silverberry (*Elaeagnus commutata*). Although most forbs benefited from burning, smooth aster (*Aster laevis*) increased the most. By the second year, rough fescue had recovered considerably but wheatgrasses and silverberry had not recovered to preburn levels. Forb coverage exceeded preburn levels. By the third year, rough fescue had nearly recovered to preburn levels. Sedge coverage declined greatly in the third year in both unburned and burned treatments; frequency remained at 100% and no obvious change in density was observed.

The 1970 spring burn stimulated reproductive performance in western porcupine grass 1, 2, and 3 years afterwards (Table 3). Rough fescue was unaffected because it did not set seed in 1970.

Table 3. Canopy coverage (%), and density of seed heads (culms/m²) for three years following the spring, 1970, fire in unburned and burned treatments.

Category	Unburned 1970 (n=30)	Unburned 1971 (n=30)	Unburned 1972 (n=30)	Burned 1970 (n=34)	Burned 1971 (n=34)	Burned 1972 (n=34)
Vegetation Class:						
All classes	317	345	281	258	318	264
Grasses	202	204	181	135	162	171
Perennial forbs	18	41	26	43	67	45
Shrubs	29	44	47	14	17	20
Species:						
Rough fescue-cover	92	85	83	36	59	75
-seed heads	0	26	0	0	26	0
Wheatgrass[1]	18	26	16	8	10	13
Western porcupine-cover	87	90	80	87	90	82
grass -seed heads	14	55	23	24	162	165
Sedge	68	55	27	65	72	28
Smooth aster	2	5	2	16	20	12
Bastard toad flax	2	7	4	5	9	6
Yarrow	1	3	2	3	6	4
Pussytoes	1	2	0	5	7	2
Silverberry	20	29	29	5	6	8
Rose	6	11	13	9	10	9
Milk vetch[2]	4	8	6	2	2	1
Number of species	30	30	27	29	28	28
May-August ppt (cm)	29	18	28			

[1] *Agropyron trachycaulum* and *A. subsecundum*.
[2] *Astragalus agrestis, A. flexuosus* and *A. striatus*.

Discussion

Rough fescue is a cool-season species that starts growth soon after snow melt. Spring fire is more detrimental than fall fire. Actively growing rough fescue plants appear to be more sensitive to fire damage than are dormant plants. Canopy coverage of rough fescue was reduced for at least 3 years when plants having 10 cm tall green growth were burned in spring, 1970. In contrast, the spring 1971 burn was conducted when green leaves were shorter. Coverage was reduced somewhat but annual production remained the same.

Weather, fuel, and soil moisture conditions are generally more favourable in spring than in fall for burning aspen forests and adjacent grasslands. However, the variable response of rough fescue to fire causes problems to the land manager who wants to conduct spring burns. In 1976, we observed 8 cm tall new growth on south exposures and hilltops on April 15 when there was no growth on flat land there were still snow drifts in the adjacent aspen forest. We burned fireguards in the grassland on April 15 but could not burn the entire area until April 28 when understory fuels of the aspen forest had dried. Burns intense enough to kill trees and shrubs could be conducted from about April 25 to May 10 in most years. However, burning at this time would reduce production of rough rescue for 2 or 3 years. Prescribed burning of the grassland may have to be done in mid-April, followed 2 weeks later by burning of the aspen forest.

Johnston and MacDonald (1967) reported that seed set of the bunch type rough fescue of the southwestern Alberta foothills was determined during the August–September period of the previous growing season. Rough fescue does not produce seed heads every year but Johnston and MacDonald could find no factors responsible for induction and initiation of the floral primordia. Seed heads of rough fescue were not produced during 1970 but they were during 1971 in the unburned treatment. Seed heads were produced during the second growing season following the spring, 1970 burn (Burn 1). Therefore, burning 3 months prior to induction and initiation of the floral primordia did not affect seed head production of rough fescue. Density of seed heads was not reduced by the fall, 1970, burned treatment (Burn 2), which indicates burning immediately after induction of the floral primordia did not affect density of seed heads. The density of seed heads of rough fescue was greatly reduced in the spring, 1971, burned treatment (Burn 3). Johnston and MacDonald (1967) report that the average height of shoot apices above the root-stem transition was 12.6 mm in October and 39.6 mm in May of the following year. Thus, greater height of the shoot apices in May would make them more vulnerable to injury during the spring, 1971, fire. Rough fescue plants in the Central Alberta aspen parkland differ from the big bunchgrass of the Alberta foothills. Rough fescue in rhizomatous, shorter, and has smaller denser bunches of tillers than its counterpart in the Alberta foothills (Johnston and Cosby 1960). Shoot apices of the rhizomatous rough fescue are probably shorter in October and May than Johnston and McDonald (1967) found for the bunch type, but the principle probably still holds true.

The canopy coverage of western porcupine grass, a warm-season grass, was not affected by spring burning. At the same time, seed production was stimulated for at least 3 years. Smoliak and Johnston (1968) found that needleandthread (*Stipa comata*) seedlings had less leaf growth and produced fewer roots than rough fescue, at low temperatures. If the two *Stipa* species, western porcupine grass and needleandthread react similarly, their growing points would probably not be elevated as high as those of rough fescue at the time of a spring burn. Fall burning reduced canopy coverage and seed production of western porcupine grass. In Idaho, needleandthread was damaged by fall fire because the plant was still growing (Wright 1971). We did not determine the state of growth of western porcupine grass at the time of the fall burn.

Daubenmire (1968a) reported from many sources that burning favors forbs over grasses. This was the case when we burned grasslands. However, the favourable response was from perennial forbs rather than from annuals. Blue bur was the only annual that increased significantly in frequency and cover. The perennial forbs that responded quickly included three-flowered avens (*Geum triflorum*), milk vetch (*Astragalus striatus*), yarrow (*Achillea millefolium*), and pussytoes (*Antennaria nitida*). Not all broad-leaved plants were favoured by burning. The half-shrub fringed sage declined. Coupland (1973) found that an August wild fire in a wheatgrass community of the Mixed prairie in Saskatchewan reduced fringed sage. Fire shows promise as a potentially desirable means of reducing this unwanted increaser on Canadian rangelands.

Daubenmire (1968a) reported that burning increased both the quantity and availability of nutrients. The black surfaces absorb incoming radiation increasing soil temperature (Geiger 1966). Increased soil temperatures and increased nutrient supply are probably responsible for the temporary increase in frequency and cover of certain perennial forbs. The lack of an invasion of annual forbs the first year after a fire is probably not due to lack of a seed source. Johnston et al. (1969) found that the native prairie top soils had an abundant supply of viable seeds.

This grassland is well adapted to fire. The perennial forbs and grasses recover quickly after burning, not permitting effective competition from annuals. This is reflected by the high total canopy cover values of 250 to 280% the first growing season after fire. The adaptation of this grassland to fire is also reflected by the insignificant change in species diversity after burning.

The effect of fire on a rough-western porcupine grass community is complex and cannot be considered simply detrimental or beneficial. We did not experience a substantial decrease in total annual production for 3 years as found after a wild fire on a western wheatgrass–northern wheatgrass (*Agropyron smithii–Agropyron dasystachyum*) community of the Mixed Prairie (Coupland 1973). That burn occurred in late August when plants were still growing.

We burned in early October and early May when most plants were dormant. However, a sharp reduction occurred in canopy coverage of slender wheatgrass (*Agropyron trachycaulum*), bearded wheatgrass, (*A. subsecundum*) and rough fescue after the May 3, 1970, burn when growth of these cool-season species was more advanced. Timing prescribed burns in the rough fescue–western porcupine grass community appears to be critical. Burning needs to be conducted as soon as possible after spring snow melt to minimize damage to rough fescue. Fall burning did not harm rough fescue but it does leave the grassland exposed to possible frost damage during winter.

Summary and Conclusions

The response of a rough fescue–western porcupine grass community to fire is complex. The effect of fire cannot be considered simply detrimental or beneficial. It varied according to stage of growth and season burned. Annual herbage production did not change after a spring or fall burn provided the plants were dormant. Total coverage of grass and grass-like plants decreased the first growing season after the burn. There was a corresponding increase in the canopy coverage of perennial forbs but no invasion by annuals. Spring burning caused a decline in the cover and seed production of cool-season grasses such as rough fescue. Fall burning reduced the coverage and seed production of western porcupine grass, a warm-season species. Spring burning when rough fescue was actively growing caused a decrease in its coverage for at least 3 years.

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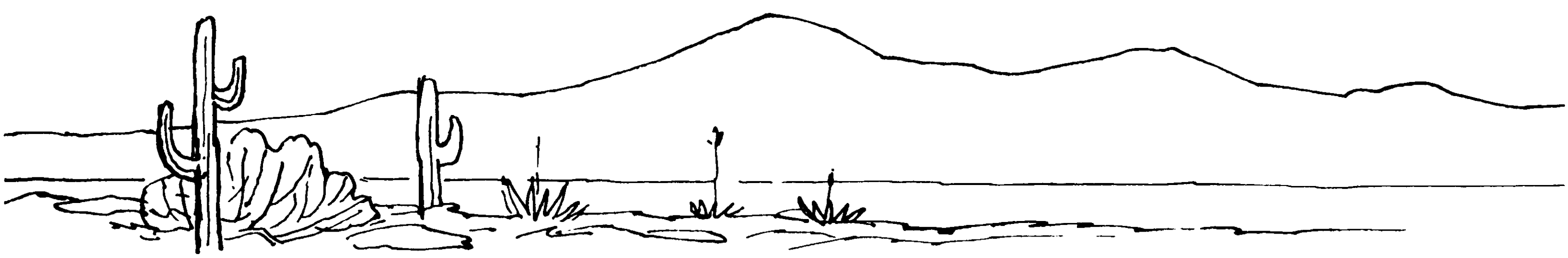

Effects of Picloram and Tebuthiuron on Establishment of Ryegrass Winter Pasture

J .R . BAUR

Highlight: Ryegrass [*Lolium perenne* L. (including *L. multiflorum* Lam.)] was established in plots 75 days (and 16 cm rainfall) after treatment with spray and granule formulations of picloram at a rate of 3.4 kg/ha. Tebuthiuron spray and granule formulations applied at the rate of 1.1 kg/ha 261 days (and 68 cm rainfall) before planting provided effective weed control and allowed successful grass establishment. Tebuthiuron spray and granules at 3.4 kg/ha, however, prevented both weed growth and ryegrass establishment when applied 261 days before planting. Sufficient residues from this rate of tebuthiuron were present after 499 days (and 116 cm rainfall) to prevent revegetation by johnsongrass on 95% of the treated area. The soil type in the plot area was a black clay loam classified as udic pellustert.

The first step in increasing the productivity of range and pastureland is the replacement of undesirable woody and herbaceous vegetation with high-quality grasses and forbs suited to the area. In many cases the herbicides that best control undesirable woody vegetation will impede or prevent the establishment of desirable forage. Consequently, it is necessary to develop cultural and application techniques that are compatible with the interrelated objectives of woody plant removal and forage establishment

Picloram (4-amino-3,5,6-trichloropicolinic acid) and tebuthiuron [*N[*5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2yl*]-N,N'* dimethylurea] control a wide variety of woody species, including post oak (*Quercus stellata* Wangenh.), blackjack oak (*Q. marilandica* Muenchh.), sumac (*Rhus copallina* L.), American and winged elm (*Ulmus americana* L. and *U. alata* Michx.), whitebrush (*Aloysia lycioides* (Cham.), javalinabrush (*Microrhamnus ericoides* Gray), yaupon (*Ilex vomitoria* Ait.), Macartney rose (*Rosa bracteata* Wendl.), and huisache [*Acacia farnesiana* (L.) Willd.] (Bovey et al. 1972, 1975; Peevy 1975; Scifres and Mutz 1976; Stritzke 1976b).

Tebuthiuron has a detrimental effect on many grasses and forbs, especially when applied during conditions of active growth. Scifres and Mutz (1976) noted that aerial application of tebuthiuron (1.1 kg/ha) in May reduced range forage production through late February, although cover the next year was improved relative to the untreated areas. Grass injury can be avoided without reducing the efficacy of the treatment by placement of granules or sprays in bands (Flynt et al. 1976) or granules in a grid pattern (Stritzke 1976a). March applications of tebuthiuron (up to 2.2 kg/ha to kleingrass (*Panicum coloratum* L.), buffelgrass (*Cenchrus ciliaris* L.) and common and 'Coastal' Bermudagrass [*Cynodon dactylon* (L.) Pers.] did not affect forage production sampled 1 and 3 months after treatment (Baur et al. 1977). June applications reduced the yield of kleingrass and the two varieties of Bermudagrass (Baur et al. 1977).

Postemergence application of picloram temporarily reduced the yield of common and coastal Bermudagrass. Yield recovery was apparent the following season (Baur et al. 1977; Bovey et al. 1974). Bovey et al. (1972) noted a similar effect of picloram on native grasses (including little bluestem [*Andropogon scoparius* Michx.], brownseed paspalum [*Paspalum plicatulum* Michx.], Indiangrass [*Sorghastrum nutans* (L.) Nash.], and threeawn [*Eragrostis* spp.]) growing in plots treated for control of woody plants. Arnold and Santelmann (1966) reported reduced yields of sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], blue grama [*B. gracilis* (H.B.K.) Lag.], switchgrass (*Panicum virgatum* L.) and big bluestem (*Andropogon gerardi* Vitman) when up to 3.4 kg/ha of picloram was applied in the seedling stage. As the seedlings matured, resistance to picloram increased so that similar applications to established rangeland did not reduce forage production (Arnold and Santelmann 1966).

Very little research has been reported on the effects of tebuthiuron on germination. We have found that germination of sorghum [*Sorghum bicolor* (L.) Moench.] and wheat (*Triticum aestivum* L.) seed was not impeded by an 8-hour exposure to a 10^{-3}M solution of tebuthiuron (Baur and Bovey 1975). Preemergence applications of 0.84 kg/ha picloram prevented the germination of sideoats grama, blue grama, big bluestem, and switchgrass (Arnold and Santelmann 1966).

The objective of this investigation was to determine the minimum time interval between application of tebuthiuron and picloram for the successful establishment of ryegrass as a winter pasture.

Materials and Methods

The plot area was a 2-ha field of black clay loam, classified as a udic pellustert located in Brazos County, Texas. The cover, predominantly johnsongrass [*Sorghum halepense* (L.) Pers.] was sprayed in October 1974 with 2.2 kg/ha glyphosate [N-(phosphonomethyl)glycine] and burned early in January 1975. The site was deep disced with an offset disc and smoothed with a tandem disc during January and February 1975. A series of 66 plots, 9- by 27-m, separated by 3-m buffer areas, was established in early March. Duplicate plots were treated with 1.1 and 3.4 kg/ha picloram and tebuthiuron on March 31, June 23, July

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This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation of this product by the U.S. Dep. Agr. or the Texas Agr. Exp. Sta., nor does it imply registration under FIFRA.

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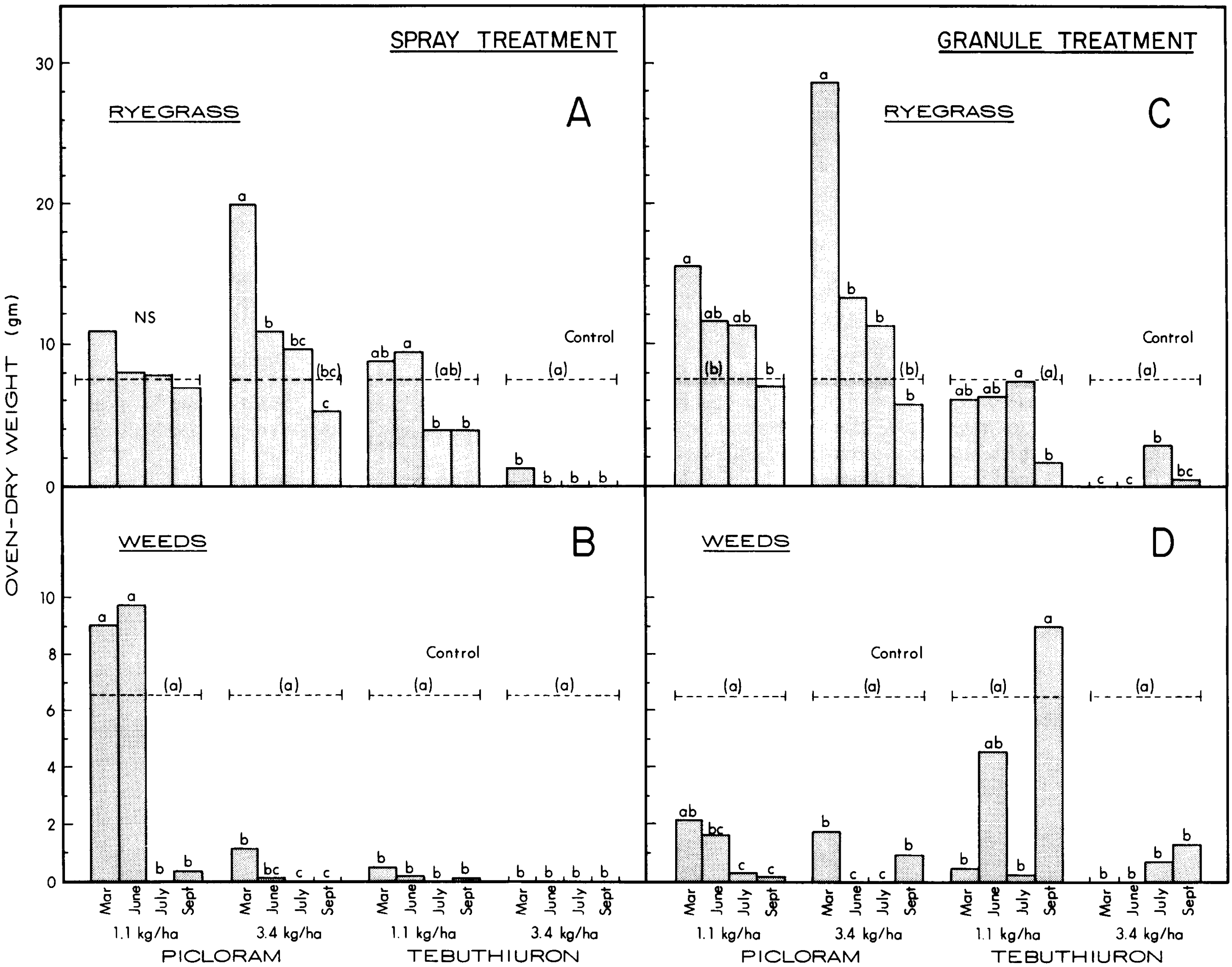

Fig. 1. *Oven-dry yields of ryegrass (A, C) and weeds (B, D) from subplots planted in October and sampled in February. Each bar represents the average of eight 30- by 30-cm clip areas evenly distributed among two replicate field treatments. Values representing the four treatment dates for each herbicide–rate designated by the same letter are not significantly different at the .05 level of probability.*

31, and September 24, 1975. Picloram was applied as the 10% granule and broadcast spray of the potassium salt formulation in 187 L/ha water. Tebuthiuron was applied as the 20% granule (1/8 inch or 3.2 mm diam) and broadcast spray of the 80% wettable powder formulation in 187 L/ha water. Granules were distributed by hand; sprays were applied with a 4.5-m tractor-mounted boom. Two untreated plots served as the control.

On August 14, 1975, the entire area was sprayed with 2.2 kg/ha glyphosate to control seedling johnsongrass. The field was burned early in September, followed by light discing of each plot. On October 1, 1975, 448 kg/ha of 13-13-13 fertilizer was applied to the plot area. After fertilization, each large plot was subdivided into three 9- by 9-m subplots. Ryegrass seed was hand broadcast at the rate of 16.8 kg/ha to one subplot per large plot on October 14, November 10, and December 17, 1975. After seeding, each subplot was lightly disced.

Grass and weed cover were periodically evaluated throughout the winter of 1975 and spring 1976. On February 20, 1976, the subplots planted in October were intensively sampled by clipping four 30- by 30-cm areas that were evenly spaced on a diagonal transect. All vegetation was clipped to within 1- to 2-cm of the ground. Ryegrass plants and weeds from each 30- by 30-cm area were separately bagged and oven dried at 105°C for 24 hours. The bulk fresh weight from each subplot was converted to dry weight on the basis of the moisture content of the subsamples.

In the spring of 1976, after all sampling and evaluations were complete, the ryegrass sod was broken with an offset disc and a seedbed prepared. On June 7, 1976, kleingrass was drilled to the plot area at a rate of 2.2 kg/ha (live seed). The lack of precipitation the next 30 days resulted in crop failure and the plot area reverted to seedling johnsongrass. The johnsongrass cover of each treatment plot was evaluated on August 1976.

Results and Discussion

October Planting

Intensive sampling in late February 1976 indicated that henbit (*Lamium amplexicaule* L.) accounted for 90% of the annual weed cover. The remaining 10% was composed of curly dock (*Rumex crispus* L.), spiny sowthistle [*Sonchus asper* (L.) Hill], and yellow woodsorrel (*Oxalis stricta* L.).

Ryegrass production in subplots treated with broadcast sprays of 1.1 kg/ha picloram was not significantly different from the control plots regardless of date of application (Fig. 1A). Weed production in these subplots, however, was dependent on the application date of the herbicide (Fig. 1B). Subplots treated in March and June (197 and 113 days, respectively, before planting) had abundant stands of annual weeds whose competitive effects apparently prevented significant gains in grass production. Picloram applied later (July and September; 75 and 20 days, respectively, before planting) effectively controlled weed production (Fig. 1B), but grass production was no better than it was in control plots (Fig. 1A), probably because of picloram residues. Increasing the rate of picloram to 3.4 kg/ha significantly increased grass production when sprays were applied in March (Fig. 1A), 197 days before planting. Later applications (June, July, and September) did not significantly affect grass production, although a trend toward decreased production is noted as the interval between treatment and seeding decreased (Fig. 1A). Picloram at 3.4 kg/ha effectively controls annual weeds when applied as early as March (Fig. 1B). The significant increase in grass production in the March-treated subplots, relative to the control plots, is probably the result of removal of the competitive effects of annual weeds, whereas the downward trend in grass production in the subplots treated in June, July, and September is probably due to picloram residues (Fig. 1A).

Picloram at 1.1 kg/ha was more effective as the granule formulation than as the spray formulation, with regard to grass production (Fig. 1C) and weed control (Fig. 1D). The significant gain in grass production (relative to the control) in subplots treated in March with 1.1 kg/ha picloram granules is probably the result of the removal of competitive annual weeds. The higher rate of picloram granules (3.4 kg/ha) applied in March resulted in a significant gain in grass (Fig. 1C) and appreciable reduction in weeds (Fig. 1D). Picloram residues from June, July and September treatments at both rates probably accounted for the lack of significant gain in grass production above control levels (Fig. 1C) in these treatments.

The broadcast spray application of tebuthiuron at 1.1 and 3.4 kg/ha resulted in excellent weed control when applied as early as March (Fig. 1B). The higher rate (3.4 kg/ha), applied as early as March, virtually eliminated grass production. The 1.1 kg/ha rate allowed grass production equivalent to that in the untreated control plots, although nonsignificant decreases in grass production occurred in subplots treated in July and September (Fig. 1A).

The effect of tebuthiuron granules at both rates was similar to that of the sprays, except that grass production in subplots receiving the 1.1 kg/ha rate in September was significantly reduced relative to the control plots (Fig. 1C). This reduction

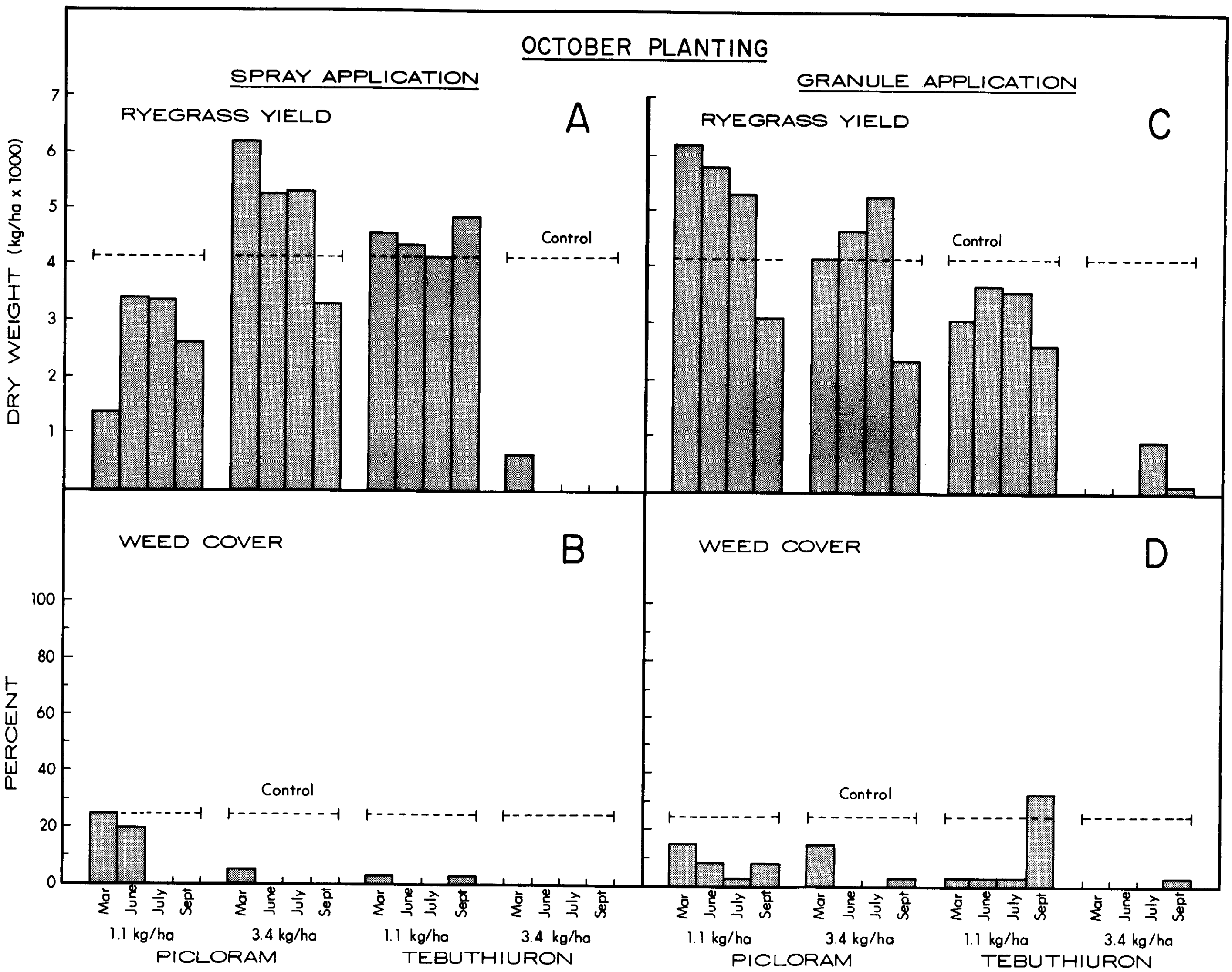

Fig. 2. *Bulk yields of ryegrass (A, C) and percent weed cover (B, D) from subplots planted in October and harvested in April. Each bar represents the average of two subplots.*

was probably the result of weed competition. The failure of the September treatment to control weeds (Fig. 1D) may have been caused by the absence of sufficient precipitation between treatment and planting to activate the tebuthiuron granules.

Bulk harvest of the October seeded subplots on April 14, resulted in grass yields and weed cover estimates that were very similar to the grass and weed yields recorded after intensive sampling of the same subplots on February 20 (cf Fig. 1 with Fig. 2). Correlation coefficients between data recorded on the two sampling dates were 0.89 and 0.72 for weed cover and grass yield, respectively.

November and December Planting

Grass yields from control subplots seeded in November and December were relatively low, and weed cover was very high (Fig. 3 and 4). The low grass yields were probably the result of the low rainfall experienced in the 30-day period after seeding (2.2 cm after November planting; 6.0 cm after December planting). The competitive effects of the dense weed cover also probably contributed to the poor grass yields in control plots.

Application of picloram in either formulation and at either rate allowed grass yields that exceeded those in control plots for both the November and December plantings. The lower (1.1 kg/ha) rate of picloram spray applied in March and June did not adequately control weeds (Fig. 3B and 4B). The same rate of picloram granules appeared to be somewhat more persistent than the spray; weed cover for the subplots treated in June was appreciably lower with granules (Fig. 3D and 4D) than with sprays (Fig. 3B and 4B). The 3.4 kg/ha rate of picloram in either spray and granular form provided good weed control and grass gains when applied as early as March (Fig. 3 and 4).

The 1.1 kg/ha rate of tebuthiuron spray and granules allowed grass yields above control levels but generally not as large as those seen for picloram-treated subplots, although weed control for March, June, and July application dates was excellent. The reduced weed control for September granule application is probably due to insufficient precipitation for activation of the granules (Fig. 3 and 4). The high rate of tebuthiuron (3.4 kg/ha) virtually sterilized the soil for at least 261 days (March treatment, December planting, Fig. 4). A total of 68 cm of rainfall was recorded between this treatment and seeding (Table 1).

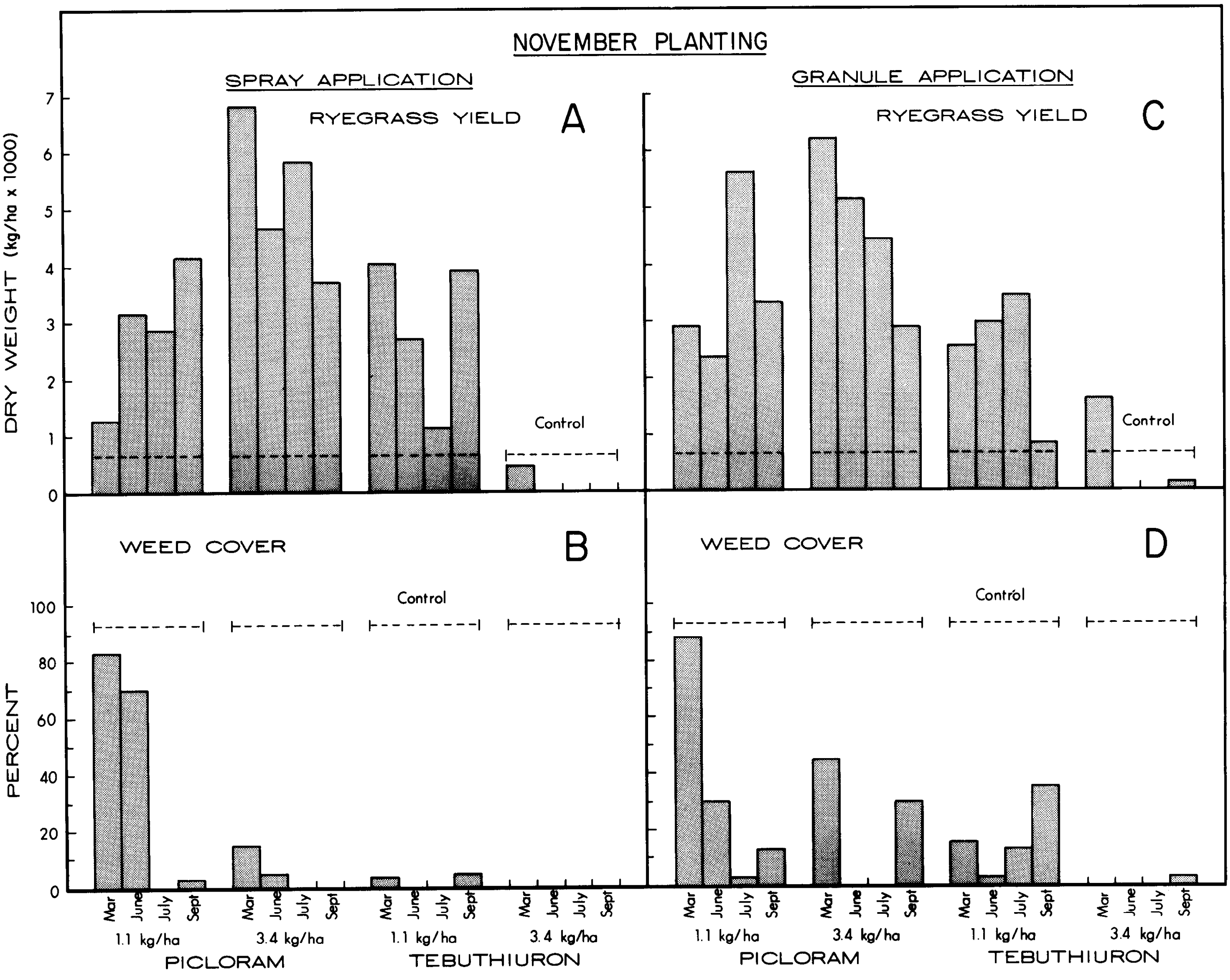

Fig. 3. *Bulk yields of ryegrass (A, C) and percent weed cover (B, D) from subplots planted in November and harvested in April. Each bar represents the average of two subplots.*

Table 1. Days and rainfall between herbicide treatment and ryegrass planting.

Planting date	Treatment date March 31	June 23	July 31	September 24
	Days			
October 14	197	113	75	20
November 10	224	140	102	47
December 17	261	177	139	84
	Rainfall (cm)			
October 14	59.4	24.5	16.1	0
November 10	65.7	30.9	22.5	6.4
December 17	68.0	33.0	24.7	8.6

Final Evaluation

Evaluation of johnsongrass on the study area on August 12, 1976 indicated that at the 3.4 kg/ha rate, both formulations of tebuthiuron were still effective in suppressing growth (Fig. 5). Precipitation for the 499-day period between the March 1975 treatment and final evaluation was 116.5 cm. Johnsongrass cover on all plots treated at 1.1 kg/ha was similar to that on control plots. The 3.4 kg/ha picloram spray and granule treatments provided a small degree of johnsongrass suppression (Fig. 5).

General Discussion

Grass production in subplots treated with tebuthiuron spray and granules at 1.1 kg/ha was generally lower than that in subplots treated with picloram spray and granules at 3.4 kg/ha (Fig. 2,3, and 4). Because these latter treatments generally gave good weed control, competition by weeds can probably be ruled out as the cause of the difference. The increased grass production in the subplots treated with picloram at 3.4 kg/ha might be the result of growth stimulation by very low residue levels of picloram. The absence of a similar increase in grass production in the subplots treated with picloram at 1.1 kg/ha might result from its dissipation to nonstimulating levels. Earlier work demonstrated significant stimulation of fresh weight of corn (*Zea mays* L.) and sorghum by picloram at 0.25 ppb and of wheat by picloram at 100 ppb (Baur et al. 1970).

Although grass production in subplots treated with picloram at 3.4 kg/ha in both formulations was generally the best noted, gains tended to decrease as the interval between treatment and

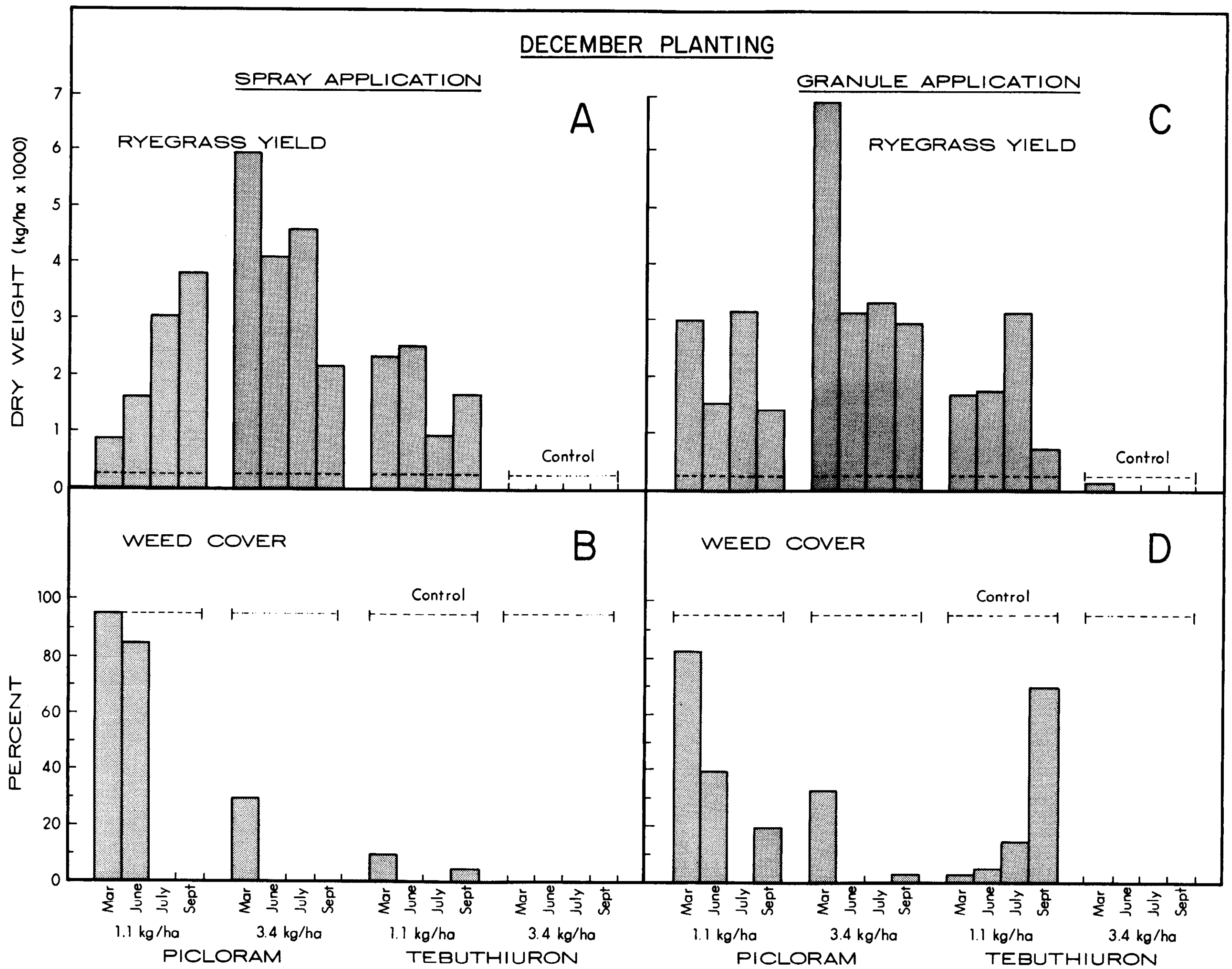

Fig. 4. *Bulk yields of ryegrass (A, C) and percent weed cover (B, D) from subplots planted in December and harvested in April. Each bar represents the average of two subplots.*

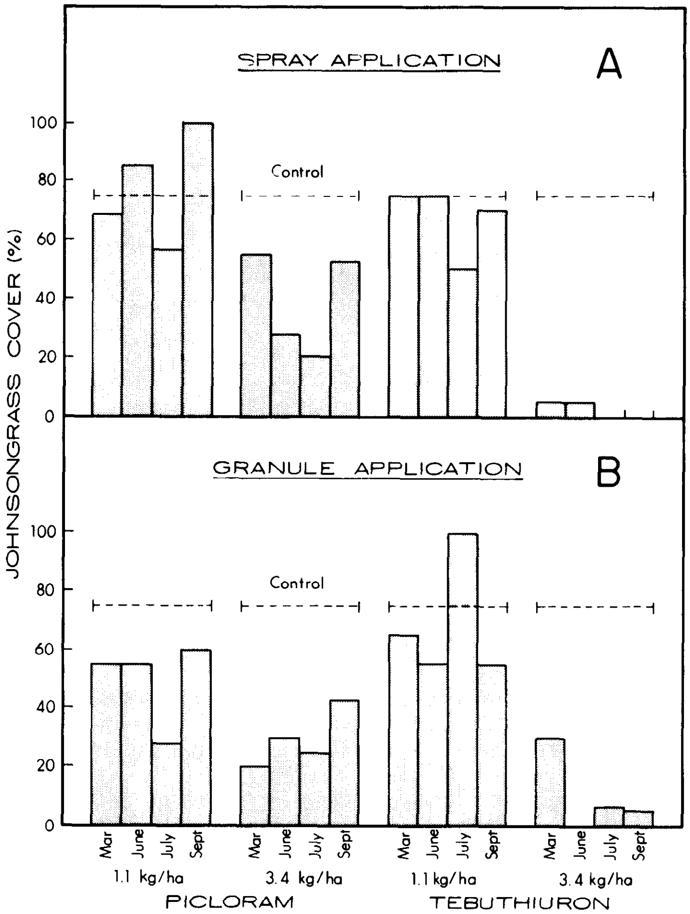

Fig. 5. *Percent johnsongrass cover on plots treated with sprays (A) and granules (B) from 499 (March) to 322 (September) days after treatment.*

ryegrass planting decreased. The absence of weeds in these subplots eliminates competition as a cause for this decrease; it could be the result of herbicide dissipation, lessening the growth stimulation noted above. Other workers, however, have shown that preemergence applications of picloram will reduce growth of barley (Herr et al. 1966) and blue grama, sideoats grama, big bluestem, and switchgrass (Arnold and Santelmann 1966).

The low degree of weed control in plots treated in September with 1.1 kg/ha tebuthiuron, as contrasted with the high degree of weed control in plots treated with the same rate of picloram, is probably a distribution phenomena related to the concentration of active ingredient in the granule. Distribution of a 10% picloram granule over the plot area would be better than distribution of a 20% tebuthiuron granule. A second possibility might be that the tebuthiuron granule requires more precipitation for release of the active ingredient than does the picloram granule.

The results of this study suggest that a ryegrass winter pasture can be established on a heavy clay site after preemergence treatment with picloram (spray or granules) at up to 3.4 kg/ha, or with tebuthiuron at 1.1 kg/ha, provided 75 days elapse between treatment and planting. The higher rate of tebuthiuron left a residue that virtually sterilized the treated area for up to 261 days. The lower rate of tebuthiuron provided good weed control for 261 days without sacrificing grass gain.

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A Rapid Method of Browse Biomass Estimation in a Forest Habitat

BOGUSLAW BOBEK AND ROGER BERGSTROM

Highlight: The accuracy and efficiency of the browse biomass estimation for a young forest plantation in central Sweden was compared using two different methods. Using the traditional harvest plot technique, the amount of browse was determined as 40.4 g dry weight/m^2; while the new technique gave a similar result, i.e., 36.4 g dry weight/m^2. The new method employs the relationship between the height-diameter index of trees and the total biomass of browse per tree as well as the regular twig count. It was found that the new technique is approximately 11 times more efficient than the regular browse harvest technique. The possibility of application of the new method in forest habitats is discussed.

The evaluation of food-carrying capacity of a forest habitat requires an accurate knowledge of its browse biomass, which is an important food component in big game diets. The ideal method of browse estimation should be simple, inexpensive, and statistically reliable, while at the same time not time consuming.

There are many methods which could be applied to measure browse biomass (Ferguson et al. 1966; Shuster 1965; Whittaker 1966; Young et al. 1967). The most accurate, although quite laborious, is the harvest plot technique. The second method which is commonly used is the twig count method (Shafer 1963); this method is convenient only if the browse is not as dense as that occurring in young forest plantations and thickets. These young stages of forest usually produce 10 to 15 times more browse biomass than mature timber stands and are the main factor increasing the food-carrying capacity of the habitat (Bobek et al. 1975). The purpose of this study was to evaluate a new, rapid technique for browse supply estimation which would be more accurate and efficient than regular harvest plot techniques.

Study Area and Methods

The study area was a young mixed forest plantation of the Grombo National Forest, which is situated in central Sweden (15°25′ E, 59°40′N). According to forestry practices in this region, the clearcut areas are commonly planted with pine (*Pinus silvestris*) and spruce (*Picea abies*). The natural regeneration of two birch species (*Betula verrucosa* and *Betula pubescens*) is very intensive here, and these species are also very abundant. Populations of moose (*Alces alces*), roe doe (*Capreolus capreolus*), and mountain hare (*Lepus timidus*) inhabiting this area are the major browse consumers (Lindlöf et al. 1974).

During the summer of 1975, the browse, i.e. current growth of leafy twigs, was clipped from the trees of pine, spruce, and birch of various ages (up to 2.5 m height); at the same time their height and diameter at 5 to 10 cm above ground level were measured. Next, correlation and regressions equations between total browse weight per tree and the diameter times height were computed separately for each tree species. The density of the other two browse species, willow (*Salix* sp.) and mountain rowan (*Sorbus aucuparia*), was very low, and the standard twig count method could be applied there. Therefore, one sample of 100 units of the current growth of twigs were clipped for each above species, and average values were determined.

Then two plots (5 × 15 m each) were established and divided into smaller subplots 3 × 5 m each. The browse supply estimation was conducted on a subplot basis; first the diameter and height of all spruce, pine, and birch trees growing within subplots were measured; and through the use of the previously mentioned equations, the amount of browse was calculated. For willow and mountain rowan the standard twig count method was used. Then the total browse was clipped and weighed. The determinations of the browse supply by the new method and the harvest technique were conducted by two persons.

The browse supply in forest habitats usually shows a clumped distribution type, which considerably increases the number of plots required and also increases research costs. There is a well-known formula which is useful for calculation of the size sample, i.e., plot numbers (De Vos and Mosby 1969:

$$n = \frac{s^2 t^2}{d^2} \quad (1)$$

where n is the number of plots required, s is standard deviation, t is the normal deviate at confidence limit level and given degrees of freedom (from t table), and d is the margin of error (arithmetic mean times designated accuracy).

Results and Discussion

The total dry weight of browse supply per tree was positively correlated with the tree height-diameter index; the correlation coefficients calculated for pine, spruce, and birch were statistically significant and varied from 0.96 to 0.98. Regression analysis of this relationship showed a similar slope for all above species, but they showed different intercept values (Figs. 1 and 2). The average weights of current growth of twigs, willow, and mountain rowan were determined as 0.84 g and 0.74 g dry weight, respectively.

Using the above data, the browse supply from the two plots was computed at 36.5 g dry weight/m^2. It was necessary for two persons to spend 135 minutes in order to determine the amount of this forage using the new technique. The regular clipping

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Table 1. Estimation of browse supply (g dry weight/m²) in the forest plantation. The data were collected using the harvest technique and the new technique (results in parenthesis) which includes correlation between the height-diameter index of tree and browse supply as well as the traditional twig count method.

Browse species	Plot I A	Plot I B	Plot I C	Plot I D	Plot I E	Plot II A	Plot II B	Plot II C	Plot II D	Plot II E	Mean
Pinus silvestris	38.8	55.0	14.4	29.3	22.4	10.3	8.7	3.0	2.5	6.6	19.1
	(35.3)	(49.5)	(11.2)	(30.3)	(20.7)	(9.1)	(7.2)	(2.2)	(2.8)	(8.0)	(17.6)
Picea abies	11.6	1.5	–	–	–	1.8	0.2	–	–	–	1.5
	(8.1)	(1.3)	–	–	–	(1.9)	(0.2)	–	–	–	(1.2)
Betual verrucosa	0.7	7.6	1.5	15.2	25.3	18.1	37.2	18.7	41.7	26.5	19.2
and	(1.1)	(8.5)	(1.2)	(10.5)	(25.0)	(8.5)	(30.0)	(15.7)	(36.0)	(36.1)	(17.3)
Betula pubescens											
Sorbus aucuparia	–	–	0.2	–	1.5	–	–	–	3.0	–	0.5
	–	–	(0.2)	–	(1.3)	–	–	–	(1.0)	–	(0.3)
Salix sp.	–	–	–	–	0.3	–	–	–	–	–	0.03
	–	–	–	–	(0.6)	–	–	–	–	–	(0.06)
Total	51.1	64.1	16.1	44.5	49.5	30.2	46.1	21.7	47.2	33.1	40.3
	(44.5)	(59.3)	(12.6)	(40.8)	(47.6)	(19.5)	(37.4)	(17.9)	(39.8)	(44.1)	(36.5)

procedure conducted by the same person gave similar results, i.e., 40.3 g dry weight/m², but the time required to do this was 1,480 minutes. Thus, the new method appeared to be 11 times more efficient than traditional harvest plot techniques (Table 1).

Using the browse biomass distribution of 10 subplots (Table 1) and assuming a 0.05 confidence limit as well as a 0.2 mean accuracy, one must clip 17 plots, 3 × 5 each, to obtain satisfactory results on browse supply in the forest plantation. For the new method (i.e., combination of twig count and the correlation between the height-diameter index and the browse supply) 21 plots were needed, but the total estimation time is considerably shorter.

The variability of the browse biomass distribution was specific to the browse species; and if calculated separately for each species, in each case the variability exceeded that of the total browse biomass. Using harvest data, the coefficient of variability of the total browse supply distribution (standard deviation/mean x 100) was calculated as 36.5%, while the

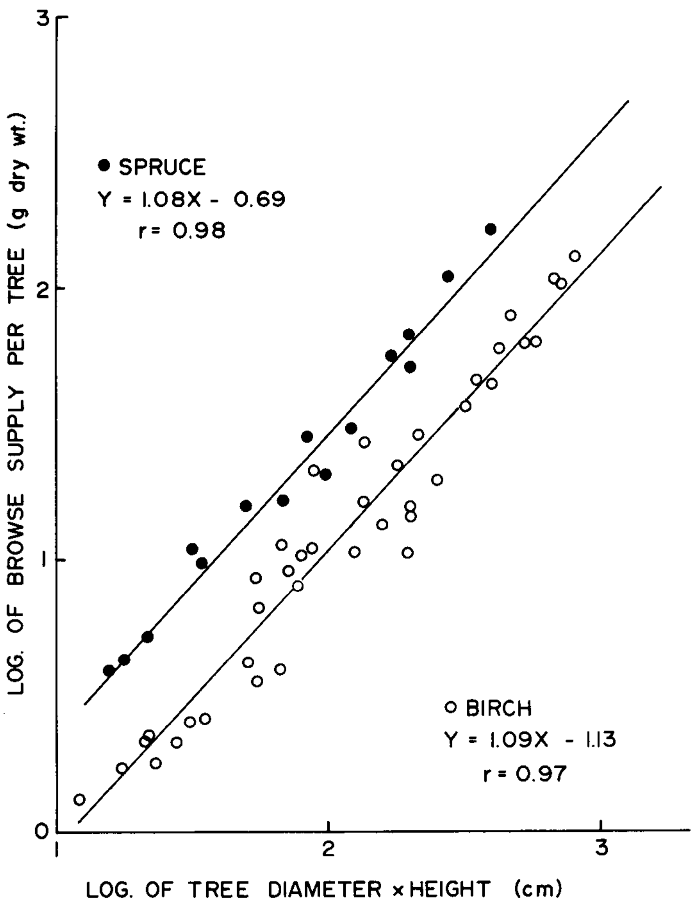

Fig. 1. *Relationship between height-diameter index of spruce (*Picea abies*) as well as birch (*Betula verrucosa*) and the total amount of browse per tree.*

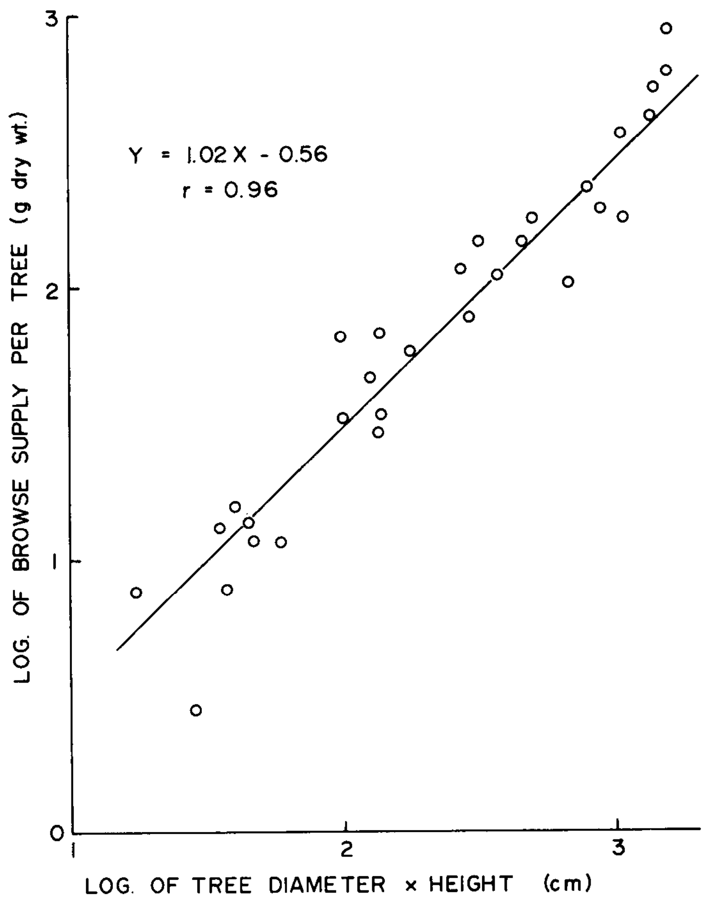

Fig. 2. *Relationship between height-diameter index of pine (*Pinus silvestris*) and the total amount of browse per tree.*

coefficients for the different species ranged from 71.8% (birch) to 300.0% (willow). A larger number of plots was required in order to obtain reliable results fo browse supply for each species. For pine it would be necessary to sample 105 such plots by the harvest method or 104 if the new method were used; spruce requires 738 or 533 plots, birch 66 or 77, and rowan 510 or 326 plots. Lack of data for *Salix* did not allow such an analysis for willow. These plot numbers calculated above will change if the plot size is changed. Larger plots considerably reduce browse variability, thereby lowering the number of plots required (Bobek and Dzieciolowski 1972).

During the last few years most wildlife biologists have been looking for good and reliable data on the amount of browse species which are critical summer and winter forage for big game. These forage studies in the field are time consuming and expensive. Therefore, it seems that the material presented here concerning the correlation between height-diameter index of trees and the browse supply may be useful and helpful in relation to certain browse species for which biomass cannot be efficiently estimated by traditional harvests or the twig count method.

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Development of Multi-Camp Grazing Systems in the Southern Orange Free State, Republic of South Africa

L.N. HOWELL

Highlight: The evolution of multi-camp schemes from non-selective grazing to short duration grazing management on Hillside Ranch in the False Karoo in the Southern Orange Free State, Republic of South Africa, is described. The grazing system resulted in the return and increase of rare and unknown grasses. The conclusion is reached that grazing management with multi-camp schemes is useful in counteracting varying climatic conditions and producing a grass cover under adverse growing conditions. In addition it is shown that livestock can produce well under such systems.

The so-called multi-camp strategies of grazing management which have evolved in Southern Africa in the past 15 years have been subjected to much discussion. Management applied in these schemes varies from heavy, relatively nonselective grazing to high intensity, short duration grazing and controlled selective grazing. It also includes a combination of two or more forms at different times of the year. Camp (paddocks of over 25 ha) numbers, even on the same ranch, may be as short as one day. They are generally never longer than two weeks. This flexible approach to management causes rest periods to differ in length according to the number of camps and the way in which they are handled. Rest periods are, however, seldom, if ever, shorter than 6 weeks.

Whatever the number of camps and the way they are used, the common objective of most multi-camp schemes is the steady optimum (not maximum) production of meat and/or wool per hectare and not necessarily per animal—though this too may be attained.

In arid and semiarid areas, however, degeneration of the veld (range) is widespread. The most important goal of multi-camp schemes in these parts is range rehabilitation. This improvement should lead to higher production.

The purpose of this paper is to summarize and record our experience and the benefits received from multi-camp grazing management on our ranch "Hillside," Springfontein, Orange Free State, South Africa, during the period 1961 to 1977.

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The author would like to thank the following scientists in South Africa, Rhodesia, Australia, the U.S.A. and France without whose advice, assistance or interest in large or small ways veld management on Hillside Ranch would not have developed as it has. "My special thanks go first to J.P.H. Acocks, the late Dr. Marguerite Henrici, Dr. J. Ebersohn and Mr. A. Savory, then to Dr. F. Morely, Dr. H. Gordon, Prof. H. Heady, Prof B.R. Roberts, Dr. J.C. Mostert, Prof J.D. Scott, Dr. P. Roux, Mr. A. Fisher, Mr. S.W. Bosman, Mr. L. Vorster, and Mons. Andre Voisin.

My appreciative thanks are due to my fellow farmers here, in Rhodesia, France (the late Andre Voisin again) and Australia (John Watson). Without their practical advice, observations, encouragement and assistance at all times I would have suffeed more setbacks than I did during the evolution of multi-camp strategies. I am also grateful for being kept informed on the basic research which has been, and is being, done in many countries besides my own by Departments of Agriculture and at Universities."

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Description of Environment

Hillside Ranch is approximately 6,000 hectares in extent, about twice the size of the average ranch in the district. Wool farming with merino sheep is the main industry of the area, with a few, small pedigree herds of either dairy or beef cattle as a sideline on suitable farms.

Soils

The soils around Springfontein are briefly:

Group 1. Red soils derived from the shales of the Beaufort series.

Group 2. Red dolerite soils, mainly of the Shortlands and Valsrivier forms.

Group 3. Yellow-brown soils derived from shales and sandstones of the Beaufort series.

Group 4. Soils of mixed origin of the Oakleaf and Bonheim forms in the low-lying areas.

Hillside Ranch lies on the watershed of the Orange River; soils belonging to groups 2,3, and 4 are found on the northern side of the farm, while groups 1,2, and 4 comprise the southern area. The country tends to be hilly with fairly gentle slopes and shallow underground waters in many vleis (low-lying areas which were probably originally marshes) on most farms, though there are few on Hillside.

At some stage of settlement in the past century, many vleis have been ploughed for lucerne (alfalfa) or cash crops. This has lowered the water table. Abandonment of such lands (paddocks) on the less productive soils has resulted in sheet and other kinds of erosion. This has hastened the deterioration of the veld.

Vegetation

Springfontein falls into the southern variation of the dry *Cymbopogon-Themeda* veld which has degenerated into false karoo (Bennie 1975). The measure of its deterioration can be gauged from the remarks of early travellers and old transport drivers. Only a century ago the vleis and deeper soils supported grass so tall that transport drivers "tied bells on their oxen's horns" when they "outspanned" to find the cattle more easily in the morning. Today this type of veld has completely disappeared. Bitterbush (*Chrysocoma tenuifolia*), bare areas and dongas (gullies) have taken its place.

Climate

Rainfall averages 440 mm with the greatest amount coming in February and March though rain can fall in any month. Snow occasionally falls in winter. Frosts usually start in April with temperatures remaining low until the end of September. Very heavy frosts—up to 9°C can also occur throughout the winter and even into October and November. The irregularity of the climate has its effect on the deteriorated false karoo veld (grassy range which has been invaded by small karroid shrubs from the true karoo of the Cape Province). Farmers generally describe a season as a "grass year" or a "bush year." These descriptions are used because rains falling mainly between October and March favour grass growth. Those occurring from March to September encourage shrubs (Chippendal 1955). Droughts, the effects of which have been aggravated by the disappearance of grass cover and the general deterioration of the veld, are fairly common. From diaries kept on Hillside Ranch, it appears as though 7.5 cm of rain are required on most farms today to achieve the growth that 2.5 cm gave prior to World War I. When droughts are combined wth a cycle of "bush rain" years, rehabilitation of grass becomes difficult.

An analysis of how and when rains fell accompanied by farmers' general descriptions of the seasons in the past 16 years is shown in Table 1. The comments on the veld's response have been taken from the rainfall record book on Hillside where descriptions are entered annually.

History of Grazing Management

Continuous sheep grazing with a few camps being rested occasionally for special purposes such a lambing or weaning was the practice on Hillside from 1908 to 1945. Highly selective grazing took place from 1945 to 1950 when sheep numbers, although conservative by district standards, were reduced in half to one sheep on 2 ha in an endeavour to combat the continued deterioration of the veld. Five years' absence from the ranch during World War II enabled me to recognise the degradation on my return in a way I would not otherwise have done. With the planning of the ranch under the 1948 Soil Conservation Act, a recommended three-camp grazing scheme carrying 600 ewes or 750 wethers per 1,000 ha was applied after 1950. Multi-camp rotations started to replace the recommended system in 1961 because the latter appeared to have failed.

This failure was manifest in two ways. The sheep did not thrive nor produce as well as they had under light, continuous selective grazing unless stocking was so low that financial returns would have been uneconomic in the smallest recession. Secondly, the veld became patchy due to selective grazing by area. It ranged from capped (bare sunbaked) ground to rank ungrazed grass. The only obvious increase to the eye was the continued invasion of the unpalatable bitterbush.

On other farms on varying veld types and in differing rainfall regions, a few keen conservation-conscious pioneer farmers tried to combat similar problems. For example, in this district of the false karoo, a farmer started putting all his sheep into one of his five camps at a time to prune down his karroid-type veld thoroughly for a shorter period than had ever been recommended. The rests after grazing depended on veld condition and

Table 1 Precipitation received at Hillside Ranch during period discussed in this paper and ranchers' views of growth conditions.[1]

	Precipition (mm)			
Year	Oct-Feb.	March-Sept.	Total	Ranchers' views
'62-63	330	251	581	Above-average good year with summer rains followed by good autumn rains. Grass year.
'63-'64	202	287	289	Good spring rains petered out into drought with late brush rains.
'64-'65	175	162	337	Drought with bush rains.
'65-'66	237	37	274	Strange grass year. Spring drought 12 inches. Jan. 20–Feb. 20. Drought declared again June.
'66-67	250	287	537	Grass about, but rain favoured bush.
'67-'68	151	187	338	Very poor season. Bush rains.
'68-'69	201	202	403	Bush rain year.
'69-70	187	101	288	Very bad drought with bush recovering a little.
'70-'71	325	152	377	Grass year but veld recovered poorly after drought.
'71-'72	425	162	587	Grass year, but good autumn rains improved bush.
'72-'73	118	200	318	Drought with bush rain which helped matters.
'73-'74	602	391	993	Fantastic rains with veld being damaged with "wet feet" while trying to recover.
'74-'75	225	125	350	Good spring petered into dry season. Grass about from last year.
'75-'76	442	312	754	Excessive rains. Grass and bush again killed by "wet feet." Grass year but good autumn rains helped bush.
'76-July, '77	182	130	312	Dry year with very dry autumn. However, veld and stock much healthier than in previous 3 years. Seedlings everywhere making up for losses from wet feet. Water table still high. Big improvement in grass species everywhere on Hillside. Much pioneer grass in district.
Average	1962-1977		449.2.	Two excessively high rainfall years have brought average up to about normal over 15 years.

[1] The classification into grass and bush rain years are based on Roux (1966). He established that, regardless of grazing management, rain falling between October and February favoured grass growth while rains falling from March to September favoured bush.

rainfall as the sheep moved from camp to camp. In the karroid *Danthonia* Mountain veld of the Sneeuwberg in the Cape Province, another rancher grazed his "suurpol" (*Danthonia disticha*) heavily while it was still palatable after he had burned his veld to eliminate invading shrubs. This gave this poorer type grazing grass a setback and reduced its competition for water and light with the better grasses during the subsequent long rest.

Fencing their ranches into small camps for better grazing control and implementation of a more rapid rotational grazing scheme was the policy of various other conservationists. They found the higher stock numbers they were able to carry improved the veld and offset the intial cost of fencing and watering handsomely.

Experimental Nonselective Grazing

Based on our experience, on that of these ranchers, on information obtained from Tukulu Ranch near Alice, Cape Province (Henrici 1940), and encouraged by a few government pasture spcialists led by the Botanical Survey Officer, John Acocks, we began what may be termed the experimental stage of nonselective grazing (NSG) in 1961. NSG on Hillside Ranch, at that time, was based on the principle of "as many stock as possible on as little veld as possible for as short time as possible followed by enough rest to enable the veld to recover completely."

With relatively minor changes we adhered to the basic fixed rest and grazing periods of the three-camp system. But cutting each large camp into four sub-camps, it was possible to arrange "a rotation within a rotation."

After trial and experiment as to the best length of the grazing period and rest, we settled for a "2 weeks on, 6 weeks off" scheme during the basic 4-months grazing period of the original large camp. This meant that each sub-camp was grazed for 2 weeks and rested for 6, during the original large camp's grazing period in addition to receiving its usual four months' rest.

Under this method it was found possible to increase numbers and financial returns without any apparent deleterious effect on the veld (Fig. 1). To given an example, in one 1,200-ha block cut into 12 sub-camps from the original three 400-ha camps, the sheep were increased steadily from 600 to 2,100. They remained at that number until the last 9 months of the 2-year 1964-1966 drought. At the end of the drought, the area was still carrying 760 sheep in contrast to the 600 previously run. While initially the sheep did not produce as much wool—4.54 kg per wether instead of 5.4-5.9 kg depending on the type of season—their production steadily improved as they became accustomed to the system. Lambs particularly showed no signs of setback. In fact, when the critical 1968-1971 drought broke and the sheep were scattered to take advantage of the first green growth, groups of all ages were found congregating in the corners of camps, indicating that they were unhappy in small flocks. They were gathered together again in large flocks and moved daily through the paddocks until sufficient growth enabled them to stay longer in camps without damaging the newlysprouted veld. Their fertility was not affected at any time, with over a 90% lamb crop, which is high for merinos. Cattle fertility was also high, going up to 98% in good seasons.

The 1964-1966 drought, however, confirmed our belief that the basic fixed rests of the three-camp system, even when reinforced by the "2 weeks on, 6 weeks off" scheme, were too short for the veld to carry increased numbers for long periods when rains did not fall for months. In 1966, therefore, a change was made to what may be called "flexible" NSG.

Flexible Nonselective Grazing

Each flock (cattle usually ran in herds with them) was as far as possible, allocated to 16 sub-camps. These were grazed for 2 weeks (or less depending on the condition of the veld and the amount of rain during the rest period) one after another. In a drought all 16 camps would be used. In a normal year perhaps only 12 would be grazed while 4 rested for a year. In an above-average rainfall year, as few as 8 might be used.

To prevent the excessive fluctuation of stock such as was experienced under experimental NSG, the size of the flock was

Fig. 1. *Picture taken in 1963 after pasture on left had been under a non-selective grazing system for 2 years.*

determined by the number of sheep units (cattle are regarded as 6 sheep units) that could be carried in good condition in 12 camps only. This gave greater protection against drought and steadier financial returns, espcially in the severe recession in wool prices in the late 1960's and the drop in cattle prices locally. It should be mentioned here that all fencing and watering of small camps, which generally averaged 50 ha so as to keep flocks and herds down to a manageable size, was paid for from profits only and not from capital. Even the original capital outlay was recovered with interest from profits.

At this time, Mr. John Acocks, Botanical Survey Officer for South Africa, who had originally suggested the lines along which we should experiment, enunciated four principles and two rules for NSG which should be followed in the karoo and the sweet grassveld (veld which can be grazed throughout the entire year without supplementary feeding save phosphate protein (urea) blocks, which build up the microflora of the stomach of ruminants enabling them to digest dry grass more easily). Sour veld in South Africa is grassveld in high rainfall regions which becomes so unpalatable and indigestible–even with blocks–that farmers have to resort to planting green grazing for their stock. Their stocking rates are, therefore, dictated by the amount of arable land they can use during winter).

The principles were: (1) The grazing period must be so short that even the most palatable and scarce plants are not exhausted by being grazed too often. (2) The minimum rest period must be long enough to allow even the most scarce and palatable plants to restore their root reserves. (3) Where veld is not in climax condition (that is, its pristine state before white settlers entered any district) the minimum rest period must be long enough to allow the best and most heavily grazed plants to seed no matter how few they are. (4) Enough animals must be put in a camp so that during the short grazing period they will graze all *grazable* species to a greater or lesser degree. The purpose of this heavy grazing is to reduce competition from the less palatable and weedy plants.

The two rules were: First, a full year's rest should be given to allow the palatable plants to grow out and produce some seed and as much palatable grazing as possible. If this is done, a rule-of-thumb stocking density (not stocking rate) for a camp should be in the region of 1 sheep per ha per 2.5 cm of annual average rainfall for the area, i.e., 100-ha camps in a 43-cm rainfall belt would have a stocking density of 1,700 sheep units while being grazing, but the total stocking rate over the 16 camps allocated to the flock or herd would be 1,700 sheep units on 1,600 ha. Second, no rotational grazing scheme should be started until good rains had fallen in a growing season.

At the NSG Conference held at Hillside, Springfontein, in July, 1968, by a majority vote the first rule was discarded as being too difficult for the farmer to implement in practice. It might also be dangerous in the hands of a farmer who exploits the soil and vegetational resources. It was suggested instead that that the number of sheep running on the area now fenced into 16 camps should be run immediately as one flock. Numbers were only to be increased slowly as rest being given the other camps produced sufficient forage. This meant in effect that the first few camps might well only carry the flock for a few days, but that the length of the grazing periods would increase up to 2 weeks in due course. Stock could then be increased when the whole area was carrying its original quota easily.

After the NSG Conference, however, the following questions appeared to require answers; "What was giving us our returns? Was it the nonselective grazing aspect? Was it the short grazing period? Was it the longer rests? Or, was it a combination of all three?"

Short Duration Grazing (SDG)

When rain came in the spring of 1968, one flock was moved twice a week, one weekly, and the third every 2 weeks.

Within 6 weeks the results became obvious. The veld recovered much faster in the rapid rotation and was ready for regrazing within the approximately 2-month rest period which was all 16 camps allowed. All flocks were immediately switched to the shortest grazing period in the summer when rain was good, the weather hot, and the veld growing fast. For ease of management, the stock stayed 3 days in one camp and 4 in the next, the period of grazing being reversed in the following round.

Stay was increased to a week when the veld was growing slowly or was almost dormant in autumn—a critical time of year when veld should not be cut too short. The "nonselective" grazing aspect received attention in winter when the grazing period was extended to 2 weeks with the consequent longer rest. This, then, is the short duration system (SDG) which has been used very flexibly indeed on Hillside Ranch during the past 9 years.

Effect of Multi-camp Schemes and Short Duration Grazing

With the change to SDG there was an alteration in the approach to rehabilitation. The emphasis shifted from the principle of nonselective grazing all the time with long rests for reclamation to the principle of improving soil surface for easier rehabilitation.

The quicker and more constant passage of the stock (sheep and cattle) through all camps has encouraged more littler lying over the whole area in summer instead of relatively few camps, as in NSG in normal and above-average rainfall years. Further, since all stock tend to concentrate on poorly covered, capped (hard sun-baked) surfaces, the ground is chipped by their feet more often between rains. This leads to better infiltration of water and easier germination of seeds.

The shorter grazing period has become a tool to prevent overgrazing as much as possible. The shorter rest has proved to be adequate for recovery and seeding when overgrazing is largely counteracted in growing periods in summer.

The use of the 2-week grazing period in winter has been retained to protect the evergreen and winter green grasses (previously unknown in the district or of very low occurrence) during their important growing season, which, we assume, due to our excessive cold may be slower than summer-growing grasses; to eliminate competition from such unpalatable grasses as tend not to go into senescence when ungrazed; and to keep the palatable plants pruned and vigorous.

Our chief barometer of veld improvement on Hillside has been the increase of grass cover everywhere with a resultant heavier carrying capacity of cattle on Hillside Ranch. Our second has been the behaviour of the valuable evergreen fodder grass (*Tetrachne dregei*). It has reappeared from completely dormant crown in many areas, including bare capped surfaces where none was previously observed. The increase in seedling establishment has been the measurement of its returning vigour. The grass is now so widespread it seems possible that it was once dominant or co-dominant with rooigrass (*Themeda triandra*) on suitable sites.

Table 2. Important species occuring on the Hillside Ranch in South Africa.

Species	Past occurrence	Present occurrence	Value	Past and present habitats
Grasses				
Fingeruthia sesleriaformis	Rare	Increasing rapidly	Almost ever green fodder.	Vleis only. Now in hills or where water flows slowly due to increased cover.
Helichtotrichon turgidum	Unknown until area receives 100-200 mm more than Springfontein	Increasing rapidly	Winter green fodder.	Vleis, slopes, and hills where water is held up by increased cover. Intermingles with summer grasses.
Hordeum capense	Ditto	Increasing rapidly	Ditto. Also described in *Grasses and Pastures* as trial as hay."	Vleis, where it also is a pioneer on bare areas.
Koeleria cristata	Ditto	Ditto	Winter green fodder.	Vleis where it intermingles with summer grasses.
Miscanthidium sorgum	Rare	Ditto	Erosion, but becomes good grazing when heavily grazed under NSG and SDG as it regrows slowly with soft leaves.	Originally vleis only where water table high. Now in hills and slopes where water flows slowly.
Panicum staphf.	Low	Plentiful	Summer, grazing, grass remaining green in dry midsummer.	Thick in vleis, replacing *Themeda triandra*. Dry slopes and hills. Pioneer on capped areas. Stands up to droughts and "wet feet."
Pennisetum sphacelatum	Rare	Plentiful in suitable sites	Very heavy carrying capacity	Formerly vleis only, now covering slopes and in hills where water is slowed. Appears it may have been dominant or co-dominant with *Themeda* on suitable sites.
Themeda triandra	Fairly common	Increasing rapidly	"Bread and butter" grass of area.	Formerly only found on good soils. Now on slopes and shallow soils.
Tetrachne dregii	Very rare	Increasing rapidly	Evergreen fodder forming large swards. Heavy carrying capacity.	Formerly vleis, now everywhere where soils are even slightly sandy. May have been dominant or co-dominant with *Themeda* and *Pennisetum* on suitable sites.
Shrubs				
Aster barbatus	Rare	Increasing rapidly	Very palatable, especially in winter.	Only found under protection of other plants. Now widespread. Rare bush not driven out by any save very thick grass.
Aster muriecatus	Relatively rare. Overgrazing made it appear to be an annual.	Increasing as a pioneer on bare areas.	Very palatable, especially in winter. Good sheet erosion plant.	Increasing, but will disappear when grass cover increases under its protection.
Atriplex semibaccata.	Rare	Increasing rapidly, especially as a pioneer on bare or thin ground	Very palatable in spring. Gives before–rain early spring grazing. Useful anti-erosion plant. Deep rooted.	Increasing on all soils but tends to disappear when grass very thick.
Chrysocoma tenuifolia	Very common	Virtually disappeared	Unpalatable invader.	Originally on all soils, but has vanished save on thin areas.
Nenas spp.	Rare	Increasing rapidly on shallow soils	Palatable. Useful antierosion bush. Heavy seeder.	Deep soils. Now spreading as pioneer on shallow soils. Disappears in thick grass.
Pentzia spp.	Wide spread	Largely disappearing.	Unpalatable invader.	Every type of soil. Now only survives in weak areas.

(continued)

Table 2 (continued)

Species	Past occurrence	Present occurrence	Value	Past and present habitats
Phymaspermum parvifolia	Relatively rare due to overgrazing	Increasing rapidly, especially on shallow soils	Good winter grazing. Palatable. Seeds prolifically when protected from overgrazing.	Found in vleis and slopes. Now taking over on shallow soils. Tends to disappear in thick grass.
Polygala virgata	Very rare	Increasing rapidly	Very palatable sedgelike plant.	On banks of spruits. Now found everywhere, especially on shallow soils.
Trichodiadema parvifolia	Rare succulent	Increasing rapidly	Very palatable and valuable in in winter and droughts.	Found only under protection of other plants. Now pioneering on most soil types except hills.
Trifolium africanum	Rare annual red clover	Increasing rapidly	Very palatable. Useful as pioneer and nitrogen fixer.	Wet places. Now found wherever grass holds up water flow, especially on bare areas above grass.

The increase of other scarce and valuable summer forage grasses and legumes as well as the appearance of previously unknown winter grasses has been as startling and rewarding as the reappearance of *Tetrachne dregei*. The value and habitat relations of these plants have been listed in Table 2. As, however, the Southern Orange Free State falls into the false karoo, the reactions of some shrubs and other plants under multicamp strategies has also been recorded in this table.

Increased grass cover has led to camps having to be reduced in size to control the length of the grazing period for the same-sized flocks. The most extreme example is a 28-ha paddock which was eroding badly. Isolated before NSG to prevent further sheet and donga (gulley) erosion, the paddock used since 1961 has had to be subdivided thus far into one 14-ha and two 7-ha paddocks.

To keep the grass further under control and grazable for sheep, cattle numbers have had to be increased. From a nominal number kept for milk supplies for the house, they have risen to 300 ranching animals for the production of weaners for feeders or directly for sale for slaughter—the quickest and highest return per annum per beast in South Africa. Although there has been a recession in meat prices in 1977 and much larger numbers have had to be sold for slaughter, those sold out of hand to local townsmen have been described as "over fat" or "almost too fat" despite the fact that they received nothing but veld grass while drinking from their mothers. Supplementary blocks have also been kept to the minimum this season due to rising costs.

Due to the rise in cattle, sheep numbers have had to be decreased. Up until 1970 they increased steadily to 900 sheep units on 6,000 ha. With the government's removal of a subsidy on fodder and low railage rates during droughts and with the vastly increased prices of such items as maize and lucerne (alfalfa), overall numbers have been decreased to just over one sheep unit per ha. It is hoped that in this manner no feeding of stock will have to be done during droughts in the future. Numbers will only be raised again when further thickening of the veld cover shows during droughts that present numbers are too conservative.

The reduced number of sheep has produced unexpected bonuses. Wool from Hillside Ranch, despite an 8% drop in the market, sold for the highest price for any clip in South Africa marketed through East London this season. The top line was typed as a speciality wool for which we had not been breeding deliberately and microned at 18.4—a figure we were told that had not been achieved in East London for fine wool for many years. Despite the fact that sheep with fine wool are supposed to produce less, we averaged 4.53 kg per sheep, which is slightly above the average for the district on veld alone. Their carcass weights were also outstanding. They compare more favourably with the South Australian merino, a large sheep with very strong wool which has never been imported into South Africa. Body weights sent us by the CSIRO (Australia) showed that our sheep weigh to a kilogram more at the same ages. Fertility is also high for the merino. How much of this is due to breeding and how much to the feed value of our improved veld is difficult to estimate. The Australians used to have a saying that "feeding is 75% of breeding." In our case the improvement of the veld has gone hand in hand with a change in stud breeders (we breed our own flock rams), so that the situation is by no means clear, but merinos bred from his stud's blood have not given him quite such good results in any other area to which he sells.

Finally, even before the excessive rains of 1973-1975, three poorly developed seasonal springs had become permanent, enabling camps to be further subdivivided without additional watering costs. One of the new seasonal springs which has appeared since 1968 is now having weirs erected near the eye to pump water to the garden. Two additional springs have become virtually permanent, though their sponges will have to become thicker for assured permanency in drought years. The water table has risen in all bore holes, running out of the top of some when rains come in any quantity. There is no record on Hillside of this occurring since 1908, though it may have happened in the latter part of the last century.

To sum up, the years 1961-1977 have shown on Hillside Ranch that grazing management with multicamp schemes has been capable of producing grass cover despite the setbacks that have occurred to certain vegetation types in floods, in recurring droughts and in "bush rain" cycles.

Better still, as ranchers, we have been privileged to enjoy the interest in our veld so vividly described by the late Fseld Marschall J.D. Smuts in his foreword to *Grasses and Pastures of South Africa*. "Once you take a little trouble to become acquainted with grasses, their attraction and their glory grow on you until at last you surrender completely to their charm. And in Africa, once you leave our deserts, it is grasses and glory all the way. At sunrise and sunset on our veld, in Spring and Autumn, when youth and maturity are in command, there is a strange fascination which no pen can describe."

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TECHNICAL NOTES

Growth Rates and Phenology of Some Southern California Grassland Species

R.W. HUFSTADER

Highlight: Growth rates of southern California grassland species showed significant correlation with rainfall from November 1972 to June 1973. Maximum growth for the species ripgut grass, foxtail chess, wild oats, black mustard, and geniculate mustard occurred during winter and early spring. Plant development for these species began in late fall and ceased by mid-spring. It was hypothesized that species characterisitics and slope exposures are important factors in plant development subsequent to germination, whereas, rainfall is critical to germination and growth rates.

California grasslands were originally comprised of perennial grasses, but introduced European annuals such as *Bromus* sp. and *Avena* sp. (Munz and Keck 1959) have become an integral part of the California flora. These annual plant species exhibit yearly cycles of growth rates and phenologies which correspond closely to weather patterns (Hufstader 1976, 1974; Major 1963). For a plant that starts from seed each year, the ability to grow and develop rapidly when conditions are favorable would seem an important factor in determining its success. Knowledge of the timing of plant growth and development and the factors affecting them is important in the management of these annual grasslands. This paper examines the growth rates and phenologies of some southern California grassland species.

Methods

The harvest method was used to measure growth rates. That methodology is described in detail in Hufstader (1976). Correlation coefficients were calculated for total rainfall (Orange County Flood Control District Station No. 86 located near this site) and the total growth rates of both slopes for each sample period.

Phenology was ascertained during 11 site visits at various intervals between November 20, 1972, and June 10, 1973, as well as during the six harvest dates, for an average of about 12 days between visits. Phenology was determined as a visual assessment of stage of growth. Six separate stages were recognized: germination (as evidenced by coleoptile presence), vegetative, immature flowers (buds), mature flowers, fruiting, and senescence.

Results and Discussion

The plant species found in the study area were ripgut grass (*Bromus rigidus*), foxtail chess (*Bromus rubens*), wild oats (*Avena fatua*), black mustard (*Brassica nigra*), and geniculate mustard (*Brassica geniculata*). Except for wild oats, each species was restricted to one slope: the north-facing slope having wild oats, ripgut grass, and geniculate mustard and the south-facing slope wild oats, foxtail chess, and black mustard. Geniculate mustard was not frequent enough for use in growth rate measurements, but was included in phenology. The growth rates of species on the south-facing slope ranged from 0.004 $g/m^2/day$ to 13.6 $g/m^2/day$. The growth rates on the north-facing slope reached a maximum of 5.4 $g/m^2/day$ and a minimum of 0.02 $g/m^2/day$. Growth rates for both slopes showed a significant correlation with rainfall (north-facing slope, $r = 0.868$, $p<.05$; south-facing slope, $r = 0.884$, $p<.05$).

For all species except foxtail chess, the maximum observed growth rates were during winter and early spring (Table 1). Foxtail chess did not exhibit a maximum growth rate until early spring, which may be related to its subdominant status (Hufstader 1976). The growth rates occurred earlier in the year than has been indicated in other studies of northern and central California annual grassland sites, where the plants exhibited maximum growth during mid-spring (Heady 1958;

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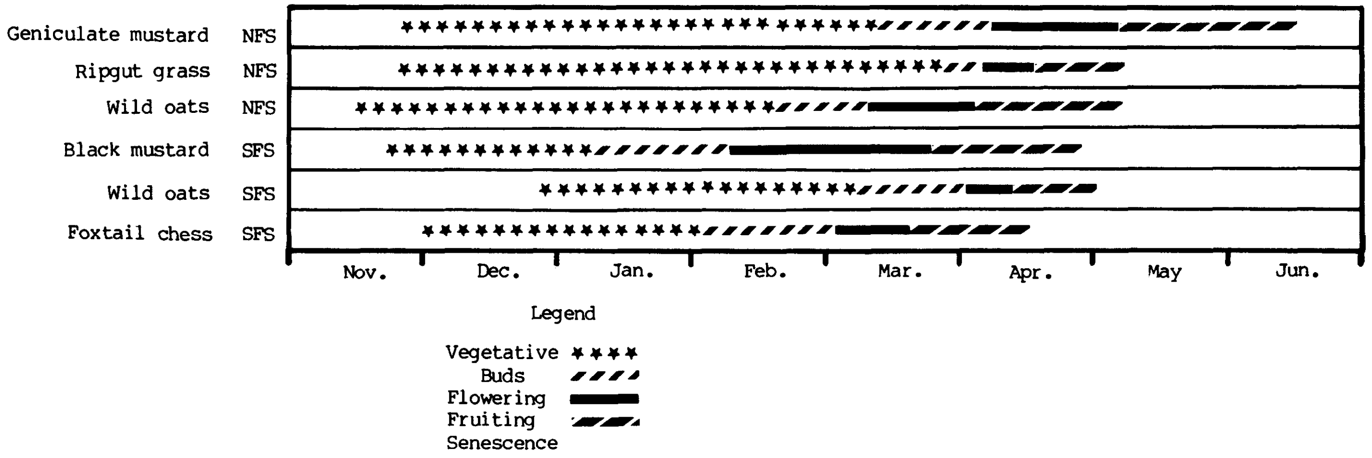

Fig. 1. *Phenology of geniculate mustard, ripgut grass, wild oats, black mustard, and foxtail chess on north-(NFS) and south-(SFS) facing slopes.*

Table 1. Maximum observed growth rates (g/m²/day).

	Growth rate	Period of occurrence
South-facing slope		
Black mustard	13.50	Feb 9 - Mar 25
Foxtail chess	0.04	Mar 25 - May 5
Wild oats	0.11	Feb 9 - Mar 25
North-facing slope		
Wild oats	3.90	Jan 7 - Mar 25
Ripgut grass	1.40	Jan 7 - Mar 25

McNaughton 1968). However, the species found on these and other similar sites do not include black mustard or geniculate mustard (Heady 1956, 1958; McNaughton 1968; White 1966; Talbot, Biswell and Horman 1939; Biswell 1956). Species, as well as latitudinal, differences may account for much of the mid-winter and early spring growth observed on this southern site.

The first rainstorm of the season (4.8 cm) fell during the third week of October but no trigger germination was noted for any of the species (Fig. 1). The second storm (7.2 cm) fell during the second and third weeks of November. Three species, geniculate mustard, black mustard, and ripgut grass germinated during the third week of November 1972. Foxtail chess germinated during the last week of November 1972. Wild oats germinated during the second week of November on the north-facing slope, but did not germinate until late December 1972 on the south-facing aspect. Heady (1958) reported that rainstorms of between 1.3 and 2.5 cm were required for germination in northern sites, but an equivalent minimal rainfall requirement was not indicated for this site.

The vegetative part of the life cycles for species on the north-facing slope average about 1 month longer than on the south-facing slope. During the mid-winter period only black mustard had buds; all other species developed buds after the first of February. None of the north-facing slope species developed buds until after late-February. Species on the south-facing slope, except wild oats, began flowering in late-winter. On the north-facing slope, only wild oats was flowering by late winter. Both mustard species took just over 3 months from bud stage to senescence; all other species took less than 2½ months. Black mustard, wild oats, foxtail chess, and ripgut grass entered senescence between mid-April and early-May. Geniculate mustard began senescence in mid-June.

Growth rates and phenology, especially germination, appear to be largely established and determined by rainfall (Major 1963; Hufstader 1976,; Heady 1958). But plant development subsequent to germination is closely related to species characteristics and slope exposure.

Competition for light may be an important factor in differential species development, as it appears to be in the production of standing crop (Hufstader 1976). This competitive factor would be most noticeable when large, broad-leaved plants, such as black mustard, dominate the upper strata. On the south-facing slope (Fig. 1) the understory plants were substantially slower in development than black mustard.

Another factor of importance to plant development is their ability to withstand the limitations of their microclimates. Hufstader (1974) showed this south-facing slope to be more limiting to dominance expression than the north facing slope. All species on the south-facing slope began senescence earlier than species on the north-facing slope. The species on the south exposure completed their entire life cycles in shorter periods of time than species on the north exposure.

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The Effect of Fire on Woody Plant Selection by Nesting Nongame Birds

J. DAVID RENWALD

Highlight: Selection of woody plants by nesting nongame birds was investigated in burns of several different ages in a honey mesquite-tobosagrass community in central Texas. Lotebush and honey mesquite were the most important plants used with nesting activity recorded in 30.3% of all lotebushes inspected. The average volume of 97 occupied lotebushes was 1.6m^3. Above-ground age of the smallest plants used averaged 6.1 years. The majority (68.6%) of the lotebushes counted in density plots were resprouts following fires and only 3.0 plants/ha were actually available as nest sites.

Brush control, or type conversion practices, are directed at the removal of woody plant species to increase forage production for livestock. In Texas, prescribed burning is a proven tool in the control of honey mesquite (*Prosopis glandulosa* var. *glandulosa*) associated with clay soils in the Rolling Plains. The subsequent loss of mesquite and other woody species in its range may adversely affect nongame bird populations breeding in these habitats.

The purpose of this study was to determine the importance of woody plants to nesting nongame birds in a honey mesquite-tobosagrass (*Hilaria mutica*) community following a 7-year burning program.

Study Area and Methods

The study area was located on the Renderbrook-Spade Ranch, 32.2 km south of Colorado City, Texas. Average precipitation is 48.2 cm per year. Slopes range from 0 to 3% on a Stamford Clay soil. Vegetation is dominated by tobosagrass, buffalograss (*Buchloe dactyloides*), and annual broomweed (*Xanthocephalum dracunculoides*), with an overstory of honey mesquite and scattered lotebush (*Zisiphus obtusifolia*).

Eight burned areas were used to evaluate nongame bird nest sites during the spring of 1975. They included areas burned in 1969 (109.7 ha), 1970 (57.1 ha), 1971 (60.3 ha), 1972 (123.1 ha), 1973 (71.2 ha), 1974 (73.2 ha), 1975 (91.1 ha), and an unburned control (140.8 ha).

Nest searches were conducted during two periods in 1975: May 1 through May 4 and June 17 through June 20 to cover early and late nesting activity. Only active nests with eggs or young were counted. Forty lotebushes and 40 honey mesquite trees in each treatment were searched for nests along random transects, with different transects used for each census period. Transects were restricted to tobosa "flats" or large areas of unbroken topography where fire had uninterrupted effect. Forty algerita (*Berberis trifoliata*), four-winged saltbush (*Atriplex canescens*), and catclaw acacia (*Acacia greggii*) plants were also inspected for nests where they occurred since these plants were not a major part of the honey mesquite-tobosa grass community.

The physical characteristics of each plant that served as a nest site were recorded to identify those plants most preferred by nesting birds. Measurements included: height, width, and length; basal growth form, i.e., single or multiple-stemmed; an physical condition, i.e., green (>50% living material) and degenerate (<50% living material). Density of woody plants was determined using two 50 × 50-m plots randomly located in each treatment.

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Table 1. Woody plant selection by nesting nongame birds following a 7-year burning program in Mitchell County, Texas. 1969-1975.

Year of burn	Plants selected as nest sites: Lotebush	Honey mesquite	Algerita	Four-winged satlbush	Catclaw acacia
1969	16	5	0	0	0
1970	14	2	0	0	0
1971	18	8	0	0	1
1972	12	6	0	0	3
1973	14	3	0	0	0
1974	0	0	0	0	0
1975	7	0	0	0	0
Control	16	4	0	0	0

Preliminary observations indicated that lotebush was a preferred nest site, therefore additional measuremens were taken on these plants. Above-ground age was estimated by counting rings from cross-sections of the three largest stems from each plant. A minimum size lotebush useful to nesting birds was calculated by taking the average dimensions (height × width × length) of the two smallest bushes used in each treatment, excluding the control.

The nonparametric Mann-Whitney Test (Conover 1971:224-229) was used to test for differences between the number of nests used in lotebushes vs. mesquite.

Table 2. Bird species use of woody plants following a 7-year burning program in Mitchell County, Texas. 1969-1975.

Bird Species	Lotebush	Mesquite
Cardinal	14	4
Cactus wren	17	10
Mocking bird	15	3
Lark sparrow	10	0
Brown towhee	41	0
Road runner	2	0
Northern oriole	0	5
Ash-throated flycatcher	0	2
Scissor-tailed flycatcher	0	4
Percent Plants Utilized	30.3%	8.8%

Fig. 1. *Nesting lark sparrow* (Chondestes grammacus) *utilizing a lotebush in central Texas.*

Results and Discussion

Nest Site Preferences and Characteristics

A search of 1,600 woody plants revealed that nesting nongame birds preferred lotebush and honey mesquite over all other woody plants (Table 1). Nest searches also indicated a significant difference ($P<0.01$) between the number of nests found in lotebushes (97) and the number found in honey mesquite (28). This preference for lotebush is of particular significance when related to woody plant densities following fire. Lotebush density for burned plots averaged 33.6 plants/ha while mesquite averaged 212.1 trees/ha. More than six times as many mesquite trees were available for nest sites yet lotebushes received three times as much use. More important, based on the minimum size lotebush acceptable to nesting birds only 3.0 plants/ha were available as nest sites. The majority (68.6%) of the lotebushes counted in density plots were basal resprouts of a prostrate, rosette growth form which appeared useless to nesting birds.

Differences in the number of nests found may be the result of the various cover requirements of nesting birds. Five of the six birds species that nested in lotebushes built cup or bowl nests, which require sturdy support (Fig. 1). This aspect of nest site selection may be especially important to grassland birds living in areas subject to climatic extremes. Years characterized by dry conditions in southwest grasslands are typified by higher than average winds and temperatures (Wiens 1974). Lotebush provides a very stable substrate during high winds that buffet other woody plants. More important, out of 97 lotebushes used by nesting birds 58 (59.7%) were single-stemmed growth forms able to withstand high winds more effectively.

Nesting bird's preferences for lotebushes, particularly the single-stem type, may also be due to the uniform, dense canopy which offers shade during high temperatures and concealment from predators. A study by Austin (1970) showed that high foliage volume was a favorable factor in shrub selection in desert riparian habitats because of the increased protection from weather and predators. Algerita grows in a form similar to single-stemmed lotebushes yet none of these plants were used by nesting birds. Although its growth from appeared suitable for nesting, undetermined factors were apparently working against its selection.

Honey mesquite trees were used by birds with more specialized nesting requirements. Northern orioles (*Icterus bullockii*) needed a high, open canopy for suspended, pouch nests; and ash-throated flycatchers (*Myiarchus cinerascens*) nested in dead limbs of mesquite trees. Birds common to both plants exhibited more flexibility in nest site choice; as a result total numbers for cardinals (*Richmondena cardinalis*), cactus wrens, and mockingbirds (*Mimus polyglottos*) were higher when both nest sites were combined (Table 2).

Although the number of bird species found in lotebushes and mesquite were the same, there was a difference in the number of plants utilized for nesting. Active nests were found in 30.3% of all lotebushes inspected compared to 8.8% found in honey mesquite. The high utilization figure for lotebush is due primarily to the large number of brown towhee (*Pipilo fuscus*) nests found (41). In deciduous woods MacArthur and MacArthur (1961) contend that one bird species cannot rely soley on one type of tree since it would have to encounter many unsuitable trees before one satisfactory type was found. In this study, brown towhees appeared to use lotebush exclusively in preference to other plants.

The height of honey mesquite trees used by nesting birds averaged 3.2 m. A volume figure for mesquite trees was not calculated since most trees had incomplete or broken canopies due to past spraying programs. All birds nesting in honey mesquite used the leafy part of the canopy as nest sites. All mesquite trees used were green, with 18 out of 28 (64.0%) originating out of the ground as single-stemmed trees with multiple stems branching from 18 to 78 cm from ground level. Lotebush volume ranged from $0.2m^3$ to $5.9m^3$. The average volume of 97 occupied plants was $1.6\ m^3$. All these plants were green with every nest located in the leafy part of the canopy. The above-ground age of the 14 smallest lotebushes used as nest sites averaged 6.1 years with a volume total averaging $0.8\ m^3$.

Effect of Fire on Woody Plants

No differences were found between burned areas in the number of plants used as nest sites except for the most recent burns. The 1974 fire was a "hot" burn conducted during a dry year under ideal burning conditions. Ample fine fuel existed in excess of 3,000 lb/acre, and the entire treatment area burned completely with all lotebushes consumed and a differential mesquite mortality depending on age and whether or not trees had been previously top-killed (Wright 1972). No lotebushes were available as nest sites a year after the burn when the census was taken and no large mesquite trees of a type used by nesting birds were present in the 1974 treatment before the burn so fire may not have had much influence on mesquite selection for nest sites.

The 1975 burn occurred under less favorable weather conditions during a wet year. Many green forbs were present to interfere with combustion of low-volatile grass fuels. This resulted in a "patchy" burn, which left many areas untouched by the fire. All seven nests found in this burn were located in large, single-stemmed lotebushes subjected to the fire but not damaged due to their higher canopies. Lower growing forms either burned down or were partially defoliated, discouraging their use by nesting birds.

A mortality figure for honey mesquite and lotebushes was not calculated since preburn densities were not known for every year of prescribed burning. However, information published by Wright et al. (1976) on this study area showed that mesquite mortality for the years 1968 through 1971 can be expected to be as high as 50% from burns during drought years or repeated burns during wet years. Fire may not have had much effect on many larger mesquite trees that were selected as nest sites on the study area. Most larger trees had been used heavily by livestock as shade and little grass cover was present under the trees to carry the fire to the stems or canopies. Fire is more effective in reducing the canopy cover of lotebush for at least a year following fire. However, lotebush is difficult to kill with fire and observations plus stem cross-sections showed that lotebushes resprout vigorously from 2 to 3 years after a fire and it may take 6 to 7 years before plants reach a closed-canopy stage useful to nesting birds.

Summary and Conclusions

Nest searches indicated nesting nongame birds preferred lotebush to honey mesquite even though lotebush occurred in far fewer numbers. Mesquite remained important since it provided nest sites for bird species not found in lotebushes. Fire may not harm older mesquite trees unless they are burned during a dry year or are subject to frequent reburns. Lotebushes are very susceptible to fire and it may take 6 to 7 years before they become suitable to nesting birds. If songbirds are to be considered in managing rangeland where mesquite and lotebush are obvious components, care must be taken to preserve adequate numbers of lotebushes and older mesquite trees. Widely scattered, individual lotebushes are preferable to several large clumps or clones since only one plant can serve as a nest site. Before burning, 5-m firelines should be dozed 10 m around at least six lotebushes/ha to insure that enough sites exist for nesting pairs. Large mesquite trees not only provide nest sites for some different species of birds, but they also function as roosts for migrating songbirds and resident owls and provide hunting perches for raptors. Based on these findings, it is suggested to the landowner that unless small numbers of lotebushes and large mesquite trees pose a serious problem to livestock operations, these plants should be spared to offer cover to nesting nongame birds.

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The Microhistological Technique: Testing Two Central Assumptions In South-Central New Mexico

K.M. HAVSTAD and GARY B. DONART

Highlight: Two central assumptions of the microhistological technique were tested for their accuracy. The estimation of particle density by relative frequency proved to be accurate for equal-sized plant fragments. Ratios of identifiable to nonidentifiable fragments were neither equal to one nor equal between grass and forb fragments.

Analysis of the botanical content of diets of livestock, big game, small mammals, and insects has become common in research. The better known dietary analyses utilize either stomach, fecal or esophageal fistula samples. The respective advantages and disadvantages of these procedures have been recognized, and the use of a particular procedure is dictated by the type of study, subject animal, available facilities, time, manpower, and information desired.

Methods for quantifying the diet sample obtained by an analytical procedure have been generalized as visual appraisal, manual separation, microhistological techniques, and microscope point techniques (Theurer et al. 1976). Of these general categories, visual appraisal and manual separation are limited by the ability of the researcher to quantify individual species in the sample diet. Hence, these methods may contain large inherent personal errors. The microscope point techniques require statistical regression procedures, determination of species weight/volume relationships, and overestimation correction factors. The microhistological techniques have become the most favored method. Sparks and Malechek (1968) have outlined the basic procedure for this method. However, its accuracy in determining dry-weight composition of masticated forage samples was not examined.

The objective of this study was to examine two central assumptions of the microhistological technique and determine if these assumptions were satisfied when determining dry-weight composition of masticated forage samples from blue grama (*Bouteloua gracilis*) foothill rangeland. These assumptions were that percent frequency can be used to estimate particle density and the percent of identifiable material is constant for each species.

Methods

Samples were collected from esophageal-fistulated steers grazing native shortgrass rangeland in south-central New Mexico. The study area was located on the Fort Stanton Experimental Ranch. The blue grama–dominated rangeland has been described by Allison et al. (1977). Dietary sampling was conducted during 1975 and 1976. Three periods representing three different plant growth stages—early summer, late summer, and mid winter—were selected for study. Handling and slide preparation of sample material as well as calculations for frequency, particle density, relative density, and percent dry-weight followed the procedure outlined by Sparks and Malechek (1968). Five slides were prepared for each sample period, and 20 systematically located fields were sampled for particle frequency and density on each slide to give 100 fields for each period. Reference material for all species present was collected during late summer. Reference slides, drawings, and photographs were utilized in identifying species within sample diets. When a particle observed in a field could not be identified, the slide was moved so that identification was improved by observing the entire particle.

This report is Journal article 651, Agricultural Experiment Station, New Mexico State Univ., Las Cruces. This study was conducted in cooperation with the Bureau of Land Management.

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Results and Discussion

The first assumption tested was that percent frequency can accurately estimate particle density, which then directly predicts dry-weight percent composition. This assumption allows the technician to reduce time spent per microscope field in quantifying percent composition and is critical for analyzing diets intensively and extensively. Table 1 presents percent composition based upon percent frequency and particle density measurements for the eight main species found in these diet samples. The only large difference between the two measurements existed for scarlet globemallow (*Sphaeralcea coccinea*) during early summer, when this species was the major individual component of the diet, and for sand dropseed in mid-winter. Percent frequency overestimated this species dietary contribution. The prominent identifying characteristic of scarlet globemallow was a relatively large epidermally attached trichome which remained intact through the grinding process. This inability to meet the assumption of equal sized particles suggests caution when encountering particles which are relatively larger than other fragments. In all other instances, percent frequency was an accurate estimator of particle density.

Table 1. Dietary composition (%) as determined by two methods.

	Early summer		Late summer		Mid-winter	
	% Frequency	Particle density	% Frequency	Particle density	% Frequency	Particle density
Grasses						
Blue grama	10.3	11.7	24.3	23.6	19.6	18.6
Sand dropseed	26.4	25.2	37.7	35.2	20.4	29.4
Mat muhly	7.8	8.7	5.2	5.4	3.5	4.2
Galleta	0.3	0.3	0.7	0.8	5.6	5.7
Three-awns	3.8	5.2	1.5	1.7	3.6	3.8
Forbs						
Scarlet globe-mallow	29.7	25.9	1.2	1.3	0.6	0.5
Carruth sage-wort	4.8	6.0	8.8	9.4	16.8	16.0
White aster	5.2	5.5	7.3	7.8	3.5	4.3

The second assumption tested was that ratios of identifiable to nonidentifiable particles within a species were equal to one. This assumption assures that each species is as identifiable as all other species and the final percent composition will accurately reflect each species proportion within the diet. This does not necessarily demand ratios to equal one, but that ratios are equal between species and between sample periods. However, it is not possible to test these ratios at the species level because some particles remained unidentified, even after the slide was moved. Ratios for forb and grass categories calculated for this study are presented in Table 2. Large differences existed between grass and forb categories within and among sample periods. As grasses matured, individual particles became more difficult to identify. Forbs were consistently more difficult to identify

Table 2. Ratios of identifiable to nonidentifiable particles.

	Early summer	Late summer	Mid-winter
Grasses	6.7	3.5	2.5
Forbs	3.1	1.4	2.0
Total	4.4	2.5	2.3

than grasses, and forbs were easier to identify during seasons when the particular forb species selected by cattle were green and immature and leafy. These ratios indicated that forbs were underestimated in relation to the grass species. However, it was difficult to attribute the wide difference to a particular species or a group of species since a nonidentifiable fragment can be placed only in a grass or forb category. The influence of unequal ratios upon quantifying percent composition was unknown. The ratios indicate that this assumption was not satisifed.

Deardon et al. (1972) also found that a few species are improperly estimated because of cellular characteristics which are either easy or difficult to identify. Deardon et al. (1975) further tested variation in microscopically discernible characteristics and showed moss fragements were high in abundance and extremely easy to identify, thus resulting in an underestimation of other species in reindeer diet studies.

The microhistological technique, even though the most favored method, is subject to a number of assumptions. Accepting these assumptions is important for utilizing the technique. However, it should be realized that these assumptions are not always satisified. Individual values of percent composition for a species of a diet should be interpreted cautiously.

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A Better Marker for Spray Projects

ROBERT L. ELDERKIN

Applying herbicides with aircraft requires a good delineation of the spray area to prevent the pilot spraying leave areas. Good delineation of exterior boundaries can be achieved in two ways; putting the treatment boundaries on well defined topographic features, or physically marking them. A better method of boundary marking can be done using white pillow casing material.

The most common method of marking is to put strips of white butcher paper on the ground weighted with rocks. This works where spraying can be done shortly after marking. Many times spraying is delayed for days by the weather and mechanical problems. The paper is attractive to livestock and subject to rapid deterioration by the elements. This requires repeated checking before spraying to ensure the markers are still in place.

A second disadvantage is low visability in the taller brush. Unless a large opening is available, the pilot has trouble seeing the markers until he is directly over them.

A solution is to use pillow casing material. It is readily available in bolts at dry good stores. A long length can be purchased intact and taken to the field. There a suitable length can be cut off and slipped completely over an entire bush or branch. Then both ends are tied tightly shut with cord or baling twine.

These markers have been used in pastures where they were heavily chewed on by both sheep and cattle as long as 2 weeks prior to aerial application. All markers were still intact and in place at the time of spraying. By being elevated on top of the brush canopy, the markers are readily visable for long distances.

The one disadvantage is they must be physically removed, as they do not deteriorate rapidly as paper does.

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Expressing appreciation to all involved with the growth and maturity of the Society for Range Management over the past four years, David A. Smith has announced his resignation effective February 28, 1979, as the Society's Executive Secretary.

Smith, who joined SRM in October of 1974, will pursue personal business interests but will remain active in Society affairs and will continue his residency in the Denver, Colorado, area.

To the SRM Membership:

With the resignation of David Smith as the Society's Executive Secretary, recruitment of a new Executive Secretary is now a top order of business. Work is going forward through an Ad Hoc Committee appointed to develop a Position Description and Procedures for Selection. In line with one of the recommendations of the Advisory Council at the recent Denver meeting, President Williamson has assigned Tom Bedell and Jack Miller of the Advisory Council to work on this Committee along with Board members Bill Laycock, Jack Bohning, and Jeff Powell. Bill Laycock will chair the Committee.

An objective of the Committee is to have Advisory Council and membership review of the Position Description prior to finalization. This will be initiated through an individual memorandum previously sent to Advisory Council members and by publishing the Draft Position Description in this issue of the *Journal of Range Management*. The *Journal of Range Management* is being used because the publication schedule more closely fits the needs for timely review than does the *Rangeman's Journal*.

The intent is to have responses in from the membership for review by the Board at their pre-Casper meeting, which is scheduled for January 10-11, 1979. This allows approximately one month from the time this information appears in the *Journal of Range Management*. Hopefully, this will make the material available to the membership for discussion in the Section winter meetings.

Individual comments should be sent by January 5, 1979, to W.A. Laycock, 130 Fairway Lane, Fort Collins, Colorado 80525.

Proposed Position Description For New Executive Secretary

A search for a new Executive Secretary for the Society for Range Management will begin as soon as a position description is finalized. Section and individual SRM member input to the content of the proposed description is essential. The proposed position description is printed below and copies have also been mailed to each Section President. *Please read the proposed position description and send any comments, suggested revisions, additions, etc., to either the duties or the qualifications, to your Section President or to:*

W.A. Laycock
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All comments must be received by the Committee preparing the search material no later than January 5, 1979, so if you send your comments to your Section President, he must receive them by late December.

The position description will be revised according to the suggestions received and will be discussed and approved by the Board of Directors at their meeting in Denver on January 10-11, 1979. A search committee will be appointed by President Williamson at that time. Vacancy announcements will be sent to universities, government agencies, other professional societies, etc. and also published in the January issue of the *Journal of Range Management*. The exact timetable for selection of a new Executive Secretary has not yet been approved, but the closing date for receipt of applications will be about April 1, 1979, and selection of a new Executive Secretary will be made about June 1, 1979.

PLEASE TAKE TIME TO READ THE DESCRIPTION PRINTED BELOW AND COMMENT.

Proposed Position Description

Draft

I. **General Responsibilities**

A. The Executive Secretary shall be the chief administrative officer of the Society under the direction of the President and Board of Directors and also shall serve as corporate secretary and treasurer.

B. The responsibilities of the Executive Secretary are assigned in the Bylaws. In general, he/she shall be responsible for supporting and coordinating the objectives, policies and programs developed by the Board and membership, and for administrative and managerial decisions, duties, and activities normally associated with carrying on the affairs of such a society through its offices, staff, Board, committees, appointed representatives, administrative and operating sections, and chapters. He/she shall issue notices of annual or special meetings, present reports to the Society at its annual meeting, and carry out other duties as assigned by, or assumed under, the broad policies of the Board.

C. In addition to the responsibilities assigned in the Bylaws, the Executive Secretary shall also supervise Society employees and assist Society officers, and Board, Editors, committees, and appointed representatives, thus serving as coordinating officer for Society affairs, exercising leadership under program and policy guidance from the President and Board.

II. **Specific Responsibilities** (Figures in parentheses approximate the percentage of time allocated to each of the four activity areas.)

A. *Duties as Coordinating Officer (50%)*

1. Carry out duties and responsibilities assigned by the President and the Board.

2. Seek and recommend to the President and Board ways the Society may, through programs, services and activities, better serve its objectives throughout the world.

3. Keep the President and Board informed on a continuing basis as to Society actions and progress, making sure incoming Board members are informed of past administrative actions and policies.

4. Represent and project the image of SRM to the general public, to other societies and organizations, and to Sections and individual members of SRM. This includes assisting the I & E Committee in the preparation and distribution of brochures and other informational materials, writing letters and making telephone and personal contacts with those requesting Society information, attending internal and external meetings, making talks to inform others about SRM, its activities and its progress. He/she also seeks and develops new sources of funds for programs and projects.

5. Submit for Board approval an annual work plan for the Denver office, outlining procedures and the necessary resources. Effectively carry out the approved work plan of the President.

6. As directed by the President and Board of Directors, maintain liaison with legislative bodies, governmental agencies and various conservation, professional, scientific and rangeland user organizations and promote Society objectives and programs.

7. Seek and develop new sources for funding special programs or projects, such as the Society building, as directed by Board.

8. Promote the increased distribution and use of Society publications; recommend and carry out programs, activities and services that will increase public understanding and acceptance of the range profession's knowledge and contributions, including the furtherance and application of Society policies and position statements.

B. *Duties as Corporate Secretary (15%)*:

1. Issue official notices of all Society business meetings, record the minutes thereof and assure their publication.

2. Issue ballots to the membership as required, send bills for annual membership renewals, and place his signature on necessary documents for the Society for Range Management as defined in the Bylaws.

3. Submit annual reports to Board and to the membership.

C. *Duties as Treasurer (15%):*

1. Handle the fiscal assets of the Society and manage its several accounts and investment portfolios as defined in the Bylaws and as instructed by the Board.

2. Prepare fiscal reports as required by government agencies.

3. Assist in the preparation of an annual budget for Board adoption and cooperate in the preparation of all financial statements and audits.

4. Cooperate closely with the Board and sign for the Society as detailed in the Bylaws.

D. *Duties as Business Manager (20%):*

1. Supervise and conduct the business operations of the Society at its headquarters in Denver, Colorado.

2. Employ and supervise the office staff to assure the Society's many services are conducted properly and efficiently to the benefit of all members, including correspondence; computerized membership records; ballots and reports; collection of dues and other monies; payment of bills; bookkeeping of accounts; background material for developing budgets, annual, and interim reports; and keeping the minutes of meetings. He/she also helps plan, coordinate, and manage the annual and summer meetings of the Society.

3. Manage monies or other resources from grants to the Society including accounting and reports required by the grantor.

4. With assistance from the staff, serve as managing editor and provide service requested by the editors of *The Journal of Range Management, Rangelands (Rangeman's Journal),* Section newsletters, and other publications or activities of the Society.

5. Work on operational and sales activities related to the Society's Life and Sustaining Membership, and other programs as adopted by the President and Board.

III. Supervision Received:

The Executive Secretary works under the immediate supervision of the President and under the general direction of the Board of Directors. Under the broad policies of the Society and direction from the President and Board of Directors he/she may: (1) direct his staff and his/her own energies in a manner that is most fruitful and efficient and (2) represent and speak for the Society. The incumbent Executive Secretary will receive an annual written performance evaluation from the Board of Directors.

IV. Qualifications

A. *Essential Qualifications:*

1. Trained and experienced in the art and science of the management of rangelands. Need not hold a degree in range management but must have had training in the sciences basic to the field and have worked in both the scientific and management aspects of it sufficiently to understand writings and hold discourse with researchers, teachers, and land administrators.

2. Have demonstrated administrative ability through business management training and/or successfully holding an administrative position to execute the duties of Business Manager as outlined in the position description of Executive Secretary, Society for Range Management.

3. Possess the interest in and ability to be a SRM spokesman on policy and philosophy of SRM and general rangeland management profession before legislative, governmental, scientific, conservation, rangeland user, and SRM groups.

4. Possess the interest in and ability to promote the international aspects of the SRM and rangeland management profession.

5. Should be interested in and skillful in communicating Society affairs orally and in writing.

B. *Other desired qualifications (not fixed requirements).*

1. Should be a member of the Society for Range Management and have participated in its activities through Section, Committee or Society offices.

2. Ability to speak and write Spanish.

3. Experience in working with volunteers.

Photo credit: Wyoming Travel Commission

Cool It in Big Wyoming

AT THE 32nd ANNUAL MEETING OF THE

Society for Range Management

CASPER, WYOMING
FEBRUARY 12-15, 1979