Water Use, Adaptability, and Chemical Composition of Grasses Seeded at High Elevations[1]

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Highlight

Soil moisture depletion varied directly with extent of top and root growth of five grass species seeded on four areas between 6,500 and 8,500 ft in northern Utah. Smooth bromegrass and intermediate wheatgrass had greater root and top growth and used the most moisture at the lower elevation site where temperatures were highest, but timothy and orchardgrass grew best at higher elevations. Timothy contained low levels of nitrogen, phosphorus, and potassium on all sites, whereas tall oatgrass and orchardgrass contained high levels.

In the mountainous West, forage production might be increased and additional water yielded from selected high-elevation range sites if deeply-rooted woody plants were replaced with suitable shallow-rooted grasses. Brown and Thompson (1965) found aspen and spruce trees removed much larger quantities of water from the soil during the growing season than did grasses. Doss et al. (1962) indicated total water use by five perennial forage species depended more upon the amount of available water in the soil than on plant species.

Bennett et al. (1964) found yields for annual forage species increased as soil moisture level increased. Nitrogen and potassium concentrations in plant tissues decreased with increasing soil moisture, but total uptake was usually higher when soil moisture was maintained at a high level. Perrier et al. (1961) observed little growth of orchardgrass when soil moisture tensions exceeded 3 to 5 bars.

The objectives of this experiment were to determine soil moisture depletion characteristics, adaptability, and the chemical composition of five grass species growing under four different environmental conditions.

Study Areas and Methods

Four experimental areas were selected in the mountains near Logan, Utah. Site 1 was on a warm south-facing slope at 6,500 ft elevation; site 2 was at 7,000 ft on an easterly aspect; and site 3 at 7,500 ft on a southeasterly aspect. Sagebrush (*Artemisia tridentata* Nutt.) and a mixture of forbs and grasses were present on these sites. Site 4 was at 8,500 ft elevation on a cool, north slope where red elderberry (*Sambucus racemosa* L.) and mixed forbs were dominant. All sites were adjacent to stands of quaking aspen (*Populus tremuloides* Michx.), and all had slopes of less than 15%.

At each site an area 41 × 101 ft was fenced, providing approximately 0.1 acre of land protected from grazing by cattle and sheep. Ten plots 13.2 × 13.2 ft (4 milacres each) were established within each fenced area.

Composite soil samples, each consisting of five subsamples, were collected on each site. A separate sample was obtained from each 6-inch-depth interval down to 36 inches. These samples were analyzed for texture and pH.

All brush was removed and each plot was plowed to approximately an 8-inch depth in the spring of 1964. Gypsum soil moisture blocks were installed in the center of each plot at depths of 12, 24, and 36 inches. On two plots, thermistors were installed at the same three depths. Soil temperature corrections were applied to all soil moisture measurements.

The plots were raked and seeded using two replications of each grass on each site. The grasses were tall oatgrass (*Arrhenatherum elatius*), intermediate wheatgrass (*Agropyron intermedium*), smooth brome (*Bromus inermis*), timothy (*Phleum pratense*), and orchardgrass (*Dactylis glomerata*).

A climatic station was placed on each site to record temperatures, relative humidity, and precipitation throughout the summer. Once a week during the summers of 1964, 1965, and 1966 the climatic stations were serviced (previous week's precipitation measured and hygrothermograph charts

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[1] Received August 27, 1968; accepted for publication March 13, 1969.

[2] Stationed in Logan at Forestry Sciences Laboratory, maintained in cooperation with Utah State University; central headquarters are maintained in Ogden, Utah.

Table 1. Percentages of soil moisture available on selected dates during the 1966 growing season.

	Depth and date											
	12 inches				24 inches				36 inches			
Site and species	5/31	7/11	8/8	8/29	5/31	7/11	8/8	8/29	5/31	7/11	8/8	8/29
Site 1												
Tall oatgrass	64	0	0	0	100	0	0	0	100	73	12	5
Intermediate wheatgrass	65	0	0	0	96	0	0	0	100	0	0	0
Orchardgrass	100	0	0	0	100	0	0	0	100	1	0	0
Smooth brome	68	0	0	0	100	0	0	0	100	4	0	0
Timothy	85	0	0	0	100	58	0	0	100	100	64	5
Site 2												
Tall oatgrass	100	0	0	0	100	1	0	0	100	52	0	0
Intermediate wheatgrass	30	0	0	0	100	1	0	0	100	61	1	0
Orchardgrass	100	0	0	0	100	5	0	0	100	100	13	4
Smooth brome	96	0	0	0	100	0	0	0	100	1	0	0
Timothy	100	0	0	0	100	0	0	0	100	100	76	2
Site 3												
Tall oatgrass	100	0	0	0	100	0	0	0	100	0	0	0
Intermediate wheatgrass	100	0	0	0	100	0	0	0	100	69	0	0
Orchardgrass	100	0	0	0	100	0	0	0	100	39	0	0
Smooth brome	100	0	0	0	100	0	0	0	100	68	0	0
Timothy	100	0	0	0	100	0	0	0	100	8	0	0
Site 4												
Tall oatgrass	100	5	0	0	100	100	24	12	100	100	100	94
Intermediate wheatgrass	100	1	0	0	100	82	0	0	100	100	100	100
Orchardgrass	100	2	0	0	100	100	0	0	100	100	92	17
Smooth brome	100	5	0	0	100	100	54	50	100	100	100	100
Timothy	100	1	0	0	100	100	1	0	100	100	100	61

changed), and readings were made on the soil moisture blocks and thermistors.

Aboveground portions of the grasses, consisting of all material above a 1-inch height, were collected for analysis in June, July, and August of 1966.

Subsamples, consisting of approximately 100 g of fresh plant material, were collected from each plot and combined into a single composite sample for each species on each site. Ether extract and moisture content were determined only on the June top samples, using the procedures outlined by the Association of Official Agricultural Chemists (1955). The percentages of nitrogen, phosphorus, potassium, calcium, magnesium, and sodium were determined in the dried and ground top material gathered on each of the three sampling dates following the methods given by Chapman and Pratt (1961). Visual observations of root concentrations were made on soil samples collected on each plot with a bucket-type soil auger in the fall of 1966. These samples were collected to a depth of 36 inches.

Results

Soil and Climatic Conditions

The climatic conditions varied considerably during the 3 years of this study. After a wet June, the remainder of the 1964 growing season was very dry, with less than an inch of rain. The summer of 1965 was exceptional, with copious precipitation throughout the growing season. The 1966 season was nearer normal, when all sites received approximately 3 inches of precipitation between June 1 and September 15.

July was the hottest month, having a mean monthly temperature 11 F greater than June and 4 F greater than August on all sites. Site 1 had 5 days during 1966 with a maximum temperature of 90 F, while sites 2, 3, and 4 had maximums of 88, 87, and 83 F for the same number of days.

Sites 1, 2, and 3 had clay loam surface soils with clay soils below the 6- to 12-inch depth. On site 4, the texture of the whole profile was silt loam to loam, silt being near 50% at all depths sampled. The soil on all sites was approximately pH 6.0.

Soil Moisture Depletion

Because rainfall was lacking in the summer after planting, no seeds germinated and sites 1, 2, and 3 remained bare during the first year. Site 4 had some germination under the cooler temperature. Soil moisture readings were collected to determine the depth to which evaporation losses were occurring from these practically bare plots. Essentially no soil moisture depletion occurred below the 12-inch depth during this summer.

During the spring of 1965, all species germinated on all sites. Soil moisture readings during this summer provided information on moisture use by developing seedlings under different climatic conditions. All soils had been fully recharged during the winter and spring snowmelt season. On site 4 the soil remained at field capacity until the second week in August, when the blocks at the 1-ft depth began to dry. In the next 3 weeks all plots there were reduced to below 40% available moisture in the surface foot, but the 2- and 3-ft depths remained at the 100% level.

On sites 1, 2, and 3 all available moisture was removed from the surface foot by late July. By mid-August most species had removed the greater portion of available moisture from the second foot. During the latter part of August and early September, three-fourths of the available moisture was removed from the third foot.

During 1966, patterns of moisture use by species and site became evident (Table 1). All species had removed the available soil moisture from the surface foot on sites 1, 2, and 3 by mid-July. Most species had also depleted moisture in the second foot; however, on site 4 some available moisture was present in the surface foot and essentially 100% available moisture was still present in the second and third foot. Three of the species on site 4 had removed the available moisture from the second foot by September, but tall oatgrass and bromegrass still had some available moisture present in the second foot.

Data collected from the third foot were most informative regarding adaptability of species under various environmental conditions. Intermediate wheatgrass and smooth bromegrass grew especially well on site 1. Top growth was 25 to 30 inches tall. Roots were abundant in soil samples collected in the upper 3 ft of soil. Both species had removed the available moisture from this portion of soil by mid-July. Orchardgrass also depleted the moisture from the upper 3 ft although top growth was less than for smooth brome and intermediate wheatgrass. Neither timothy nor tall oatgrass removed all of the available moisture during the summer on this site.

All species responded similarly on sites 2 and 3, where soil moisture was essentially depleted by all species throughout the surface 3 ft. Tall oatgrass and timothy grew taller on these higher elevation sites than on site 1.

On site 4 intermediate wheatgrass and smooth brome responded poorly compared to growth on other sites. This was reflected in the pattern of moisture depletion. Neither species removed the available soil moisture below the 2-ft depth. Root systems were poorly developed and top growth was less than half as tall as on site 1. Timothy and orchardgrass grew best on this site, where temperatures were cooler and humidity higher. These two species not only produced taller plants but also extracted greater quantities of moisture from the third foot of soil.

Table 2. Changes in the nutrient content (percent) of grasses with season, expressed as an average of four sites.

Species and date	N	P	K	Ca	Mg
Tall oatgrass					
June 15	2.42	0.357	2.68	0.29	0.020
July 26	1.46	.223	1.86	.36	.027
Aug. 25	1.11	.167	1.46	.41	.044
Intermediate wheatgrass					
June 15	2.22	.341	2.33	.25	.013
July 26	1.25	.199	1.47	.33	.018
Aug. 25	1.07	.155	1.16	.31	.026
Smooth brome					
June 15	2.17	.287	2.60	.76	.026
July 26	1.21	.147	1.75	.91	.044
Aug. 25	1.27	.135	1.57	1.01	.071
Timothy					
June 15	1.59	.238	2.01	.31	.024
July 26	0.96	.145	1.25	.58	.042
Aug. 25	0.83	.127	1.07	.37	.031
Orchardgrass					
June 15	2.43	.318	3.16	.22	.026
July 26	1.44	.196	2.18	.56	.080
Aug. 25	1.14	.168	1.76	.41	.061

Plant Composition

Striking differences with respect to chemical composition were noted between species growing on the same site. Table 2 shows the changes in composition that occur as plant development advances. Three of the elements measured—nitrogen, phosphorus, and potassium—showed a large decrease with increasing age of the plant. Calcium, magnesium, and sodium increased with plant age on most species. These changes influence the quality of feed available for livestock consumption as the season progresses.

The nitrogen content was high during June on all sites, especially site 4, and for all species except timothy. Site differences became less apparent as plants matured. Orchardgrass and tall oatgrass were highest in nitrogen throughout the summer, except for smooth brome in August.

Phosphorus levels were highest in tall oatgrass and lowest in timothy. Smooth brome was also low in phosphorus compared to the other species.

Potassium was closely correlated with both protein content and moisture content of various species. In both moisture content and potassium level, the species showed the same ranking, in ascending order: timothy, intermediate wheatgrass, smooth brome, tall oatgrass, and orchardgrass. In June the plants on site 4 contained approximately 7% more moisture and 0.6% more potassium than on the other sites.

Smooth brome had two to three times as much calcium as the other species. Intermediate wheatgrass was lowest in both calcium and magnesium.

Calcium-magnesium ratios were distinctive for each species. During June, smooth brome had a ratio of 29.2 : 1 while orchardgrass had a ratio of only 8.5 : 1. Other species were intermediate between these extremes. By August the ratios had dropped to 14.2 : 1 and 6.7 : 1, respectively, showing magnesium was increasing more rapidly than calcium.

Another variable, important in nutrition, was the quantity of ether extract, or fat content. Measurements were made on June samples only. A range from 4.67% for tall oatgrass to 2.51% for timothy indicates energy values are different between species growing on the same site.

Discussion and Conclusions

Climatic differences among the four sites were reflected in plant growth, in soil moisture depletion, and in the chemical composition of the five grass species. Probably the main factor influencing plant growth and development was the difference in temperature regimes, including both air and soil temperatures. The temperature regime would affect the water requirements as well as water and nutrient availability.

The depth to which soil moisture was depleted during the growing season depended on the quantity of top growth and the extent of root systems produced by each species. Available soil moisture was completely depleted to at least 3 ft by grasses well adapted to the sites tested. Therefore, if these grasses were used to replace deeply rooted trees and shrubs to improve water yield, no significant increase could be expected from the upper 3 ft of soil.

During the period when no vegetation was present on the plots, available soil moisture remained near field capacity at depths below 1 ft. Losses by evaporation would therefore be insignificant on these sites at lower depths.

The nutrient content of the various species was not a good measure of their ability to become established, as all species had similar patterns of change in composition with elevation, even though growth was not equal. Plant height and depth of rooting, the latter indicated by soil moisture extraction patterns, are better measures of species adaptability.

Essentially the same ranking of species applies for moisture, potassium, and nitrogen contents on June samples. Orchardgrass had the highest values, followed by tall oatgrass, smooth brome, intermediate wheatgrass, and timothy. Sullivan (1962) states moisture content of vegetation is related to forage quality. Because of the interrelations between the plant constituents measured, it might be possible to predict the ranking of various species on a given site as to forage quality if their moisture contents were known.

Seasonal changes in composition were great for all nutrients and for all sites. These seasonal changes and site variations are related to climatic conditions and the developmental stage of the grasses. The variation among species is important to livestock nutrition and should be considered in selection of grass mixtures for seeding rangelands. However, because plant part selection by animals is important in balancing their diets, analyses involving the entire aboveground portion can only be used as a rough indicator of forage value.

If the major reason for converting to grass is to increase water yields from an area, then greater treatment effects would probably be obtained on higher elevation sites where evapotranspiration rates are relatively low and annual precipitation is greatest. Orchardgrass appeared to be the best species on the high-elevation site, as it produced an abundance of high-quality forage from vigorous plants.

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