
<table>
<thead>
<tr>
<th>Stage of development</th>
<th>Approx. date of clipping</th>
<th>0</th>
<th>4</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2 inches of spring growth</td>
<td>April 3</td>
<td>250*</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>5-7 inches of spring growth</td>
<td>April 24</td>
<td>180**</td>
<td>210**</td>
<td>—</td>
</tr>
<tr>
<td>Boot stage</td>
<td>May 11</td>
<td>110*</td>
<td>160*</td>
<td>250*</td>
</tr>
<tr>
<td>Maturing, heads yellowing</td>
<td>June 27</td>
<td>240**</td>
<td>250*</td>
<td>380*</td>
</tr>
</tbody>
</table>

1Means having the same letter in the superscript do not differ significantly at the 5% level using Duncan's Multiple Range Test.

Carbohydrates are low (McIlvanie, 1942), produced no regrowth. Delaying defoliation until the maturing stage would allow season-long root growth and accumulation of carbohydrates in roots.

From the standpoint of bluebunch wheatgrass survival, the same principles evidently apply in southeastern Washington as in northern Utah (Stoddart, 1946). Early- or late-season grazing appear less damaging than grazing in mid-season. But the possibility of trampling damage in early spring or loss of nutritive value as bluebunch wheatgrass matures (Stoddart, 1946) should be considered in developing a grazing plan.

Summary

Bluebunch wheatgrass on native range was clipped once each year in 3 consecutive years at 0, 4, or 8 inches above the ground. Clipping treatments were imposed at four stages of development. Bluebunch wheatgrass was more susceptible to injury in the boot stage than in earlier and later stages of growth. Measurements in the fourth year, during which clipping treatments were not imposed, indicated that ground-level clipping of plants in the boot stage in the 3 preceding years decreased yield 70%.

LITERATURE CITED


Brachiaria dura, a Promising New Forage Grass

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Highlight

In Barotseland, Zambia, in Central Eastern Africa a grazing and ecological survey has revealed Brachiaria dura to have unusually favorable characteristics as a forage grass on sandy soils of low fertility. Chief among these characteristics are relatively high protein content, a long period of succulence, and a special root adaptation to sandy soil.

Range managers are always on the lookout for promising new grasses, especially those which show some adaptability to adverse growing conditions. During a recent ecological study in Barotseland in Zambia, I became convinced that Brachiaria dura (a signal grass) has unusually valuable characteristics as a range forage species on low quality sandy soils where rainfall is abundant. The purpose of this paper is to state what is presently known about this grass and to discuss its possibilities.

Soils.—The loose Barotseland upland sands have a complex history. Starting from river alluvium and lake deltas this sand has been reassorted by stream, wave, and wind action. In the process it lost its clay and silt content. It has been bleached by organic solvents seeping out of the peat formations formed in the past on the floor of shallow seasonal lakes, then blown from exposed lake shores into lacustrine dunes. This resulted in a loose, uniform, mainly coarse sandy soil consisting of rounded and frosted silica dioxide particles, with: a) low mineral content, b) low organic content, c) low absorption complex, d) high leaching potential, and, e) poor water retention capacity.

All this soil has to offer to the plants living on it is a loose well-aerated but inert medium in which to anchor. Only plants with special adaptions can thrive in this kind of solum. Some trees find this in a very deep penetrating and wide spreading root system, for access to subsoil moisture and to cover a wide range to obtain the scarce minerals. Some grasses like Brachiaria dura encase their roots by exuding selective absorbent resins (polysaccharides) and covering them with

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falty masses of roothairs (Verboom, 1994). Possibly this root case assists absorption of nutrients and retention of moisture.

Vegetation. — The loose Barotseland sands are covered with fire-climax woodland, which is disappearing as a result of land-clearing and fires. Not being fire-resistant, the Rhodesian teak *Baiikiae plurijuga* is doomed unless protected. The main woodland species are: *Burkea africana*, *Guibourtia coleosperma*, *Ricinodendron rauteeni*, *Pterocarpus angolensis*, *Diplorrhynchus condilocarpon*, *Erythrophloeum africanum* and *Brachystegia spiciformis*. *Cryptosepalum pseudotaxus* in the north replaces *Baiikiae plurijuga*. Sparse grasses occur under the trees (Trapnell, 1957).

The normal cropping period for the fields in this area is 2 years. The crops are bullrush millet (*Pennisetum typhoides*) and cassava (*Manihot utilissima*). The exhausted fields are left fallow for many years. They revert first to a sparsc shrub-grassland followed by a fire-climax woodland. The shrub-grassland fields form the main upland grazing. The main shrubs are *Daphia obovata* and *Bauninia macrantha*. The grasses are mainly *Aristida*, *Eragrostis*, *Loudetia*, *Digitaria*, and *Brachiaria* species (Crook, 1950). The carrying capacity of the fields reverting to bush is low. On these old deserted fields *Brachiaria dura* is an abundant species.

Botanical Description. — *B. dura*, Stapf. is a perennial, about 2½ ft high, compactly caespitose on a short oblique rhizome with intravaginal innovations. Culms slender, wiry, erect and simple, up to ½ ft. more or less geniculate and branched, terete or slightly compressed, glabrous or sometimes sparingly and minutely hairy below the nodes. Leaf-sheaths tight, terete or slightly compressed, very firm and hard, striate, the basal up to over 3 in long, hairy, long-persistant and coating the innovations and flowering culms, the others glabrous; ligules a narrow ciliolate rim; blades narrowly linear, convolute, very wiry, up to over 1 ft long, 1½ in wide when flattened out, ½ in in diam. in the convolute state, pale green, glabrous except for a beard (lower leaves) or some fine pubescence at the base; blade of the uppermost leaves suppressed, the sheath tapering gradually to an acute point. Inflorescences reduced to a solitary terminal upright straight or slightly arching spiciform raceme (Fig. 1). Complete description is given by Frain (1934).

![Fig. 1. Herbarium specimen of *Brachiaria dura* from Zambia, Africa.](image)

Vegetative Characteristics.—While normally plant roots have only active hair roots near their growing tip, *B. dura* has masses of root hairs from tip to root base 1-3 mm long, intermingling with the sand particles. Also a vegetable glue (probably polysaccharides) is exuded by these roots, knitting the loose sand together. In other words, this grass creates its own soil complex, forming an absorbent mantle of soil around its roots. The lack of water retention and ion absorption in the loose sand is thus overcome. This important characteristic evidently promotes forage production.

The lower part of the shoots is covered with a dense mass of falty hairs. The tufty ligule catches dew from the rolled-up leaf, and this moisture finds its way to the root base. During the dry season the leaves are rolled up to expose a minimum evaporation surface. In the wet season the leaves flatten out to have a maximum surface for photosynthesis. The plant attains an average height of 18 inches in Barotseland, and stays green and sets seed the whole year round.

Other Site Factors. — *Brachiaria dura* occurs abundantly in Barotseland at an average altitude of 3000 ft, longitude 22° to 25° 30' latitude 14° to 17° 45'. Rainfall comes in summer from November to March, 35-40 inches. Barotseland minimum temperatures are for June the coldest month, 53°F in the north and 38 in the south. Mean maximum for October the hottest month, 87 in the north and 95 in the south. There is frequent frost in the south in June, July.

Discussion

In reseeding trials at Mongu, capital city of Barotseland, germination difficulties were encountered. Like some other tropical grasses, *B. dura* may have delayed germination. Seed planted in the early part of the rainy season (November) failed to germinate due to lack of sufficient moisture in the soil. Later plantings are expected to do better. In the early rainy season smut attacks the seeds. Transplanting with new shoots was successful. Further reseeding and fertilizing trials are planned.

*B. dura* has a protein content above the average for the upland grasses of Barotseland, as the chemical analysis in Table 1 reveals.

Since *B. dura* has the excellent grazing quality of remaining green and succulent long after companion forage species have become dry, grazing animals seek out this grass and graze it heavily. Nevertheless, it appears to withstand heavy grazing well.

The characteristics of *B. dura* are such that it might grow well on sandy soils in eastern Texas.

Table 1. Chemical analysis of *Brachiaria dura* compared with associated forage species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Ether</th>
<th>CP</th>
<th>CF extr.</th>
<th>Ash</th>
<th>NFE</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>B. dura</em> Leafy stage</td>
<td>7.5</td>
<td>41.3</td>
<td>2.4</td>
<td>2.9</td>
<td>45.9</td>
</tr>
<tr>
<td>Flowering</td>
<td>6.4</td>
<td>43.3</td>
<td>2.2</td>
<td>2.4</td>
<td>45.7</td>
</tr>
<tr>
<td>All grasses Composite mix flowering</td>
<td>4.7</td>
<td>43.1</td>
<td>2.1</td>
<td>3.5</td>
<td>46.8</td>
</tr>
</tbody>
</table>
Summary

Brachiaria dura appears to be the most promising indigenous forage grass for the Barotseland loose sands; yet so far as I have been able to ascertain, this species has never been investigated for grassland improvement before. Further research into its unique adaptations to drought and infertile loose sands may well be rewarding. It should be tried in other parts of the world where similar soil and climatic conditions prevail, such as eastern Texas.

Acknowledgments.—To Mr. I. S. Hutcheson, Director, Department of Agriculture, Republic of Zambia, for permission to publish this paper; Mr. Floyd D. Larson, Agricultural Advisor, U.S. Agency for International Development, for editing; Mr. J. B. M. Vogt, Agricultural Chemist, Mount Makulu Central Research Station of Zambia, for chemical analyses of samples; and systematic botanists of Salisbury Herbarium, Rhodesia, and Kew Herbarium, London, for identifications of the Gramineae and Leguminoseae.

Root Systems of Four Desert Grassland Species on Grazed and Protected Sites

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Highlight

Root systems of species of Aristida, Bouteloua and Trichachne were restricted to the upper 7 inches of soil, with depth penetration of roots influenced by characteristics of the soil. Grazing affected root development by reducing the amount of branching of first-order roots and, in 2 species of Bouteloua, by decreasing total root density. Root diameter was not affected.

The root system of a plant represents almost one half of the total material produced by that plant, and must be taken into account when the effect of environmental factors on plant development are studied. Several early clipping experiments (Biswell and Weaver, 1933; Robertson, 1933; de Peralta, 1935) found that root development was affected by defoliation and reduction of photosynthetic surface. Crider (1955) observed root growth directly and noticed a cessation of growth for a period of time dependent on the severity of the clipping treatment. Troughton (1937) reviewed the literature on underground organs of herbage grasses and listed many other studies on the effects of defoliation on root development. A recent study by Schuster (1964) showed that heavy grazing reduced total root weight, depth of penetration and branching of the roots of several grass species growing under natural conditions in Colorado.

The present study investigated the effect of grazing on the root development of four species of native grasses of the southwestern United States, excavating grass plants growing in the field under natural conditions but subjected to different grazing pressures. The species studied included threeawn (Aristida glabrata (Vasey) Hitch.), sideoat grama (Bouteloua curtipendula (Michx.) Torr.), slender grama (Bouteloua filiformis (Fourn.) Griffiths) and Arizona cottontop (Tri
cachne californica (Benth.) Chase).

Study Area and Methods

The field work was carried out at the Santa Rita Experimental Range, about 25 miles south of Tucson, Arizona, with an average annual precipitation of 16 inches. A soil survey of the region (Youngs et al., 1955) classifies the soil at the study site as Tumacacori coarse sandy loam, a soil which "absorbs and holds moisture well, releases it readily to plants, and is sufficiently rich in humus and nitrogen to support vigorous plant growth." The study site was located at Parker Station, 4300 ft above sea level. An enclosure protecting vegetation from grazing by livestock had been established there in 1935, within which a good stand of grama grasses was found. The area outside the enclosure had been grazed by cattle under varying intensities during the history of the experimental range, but the presence of a cow path along the edge of the enclosure indicated fairly constant presence of cattle in the area whenever the pasture was in use. Measurements were made on root systems of at least 10 individual plants of 4 species, both within and outside of the enclosure to detect any differences which could be attributed to differences in past grazing pressures.

To expose the roots, a method developed by van Breda (1937) was adopted. Soil was removed from around the plant roots by means of a jet of compressed air, provided by a portable air compressor. In some areas of compacted soil, an ice pick was used to loosen the soil before blowing. Fig. 1 shows the root system of a grass plant after excavation by this method.

The density of the exposed root system was estimated by counting the number of roots which passed through a 1 x 2-inch wire frame, held within 3 inches from the base of the plant; a total of 4 counts were made for each plant. An independent estimate of root density was made by counting the number of secondary branches along the first 6 inches of main root, making 4 or more counts per plant, depending on the amount of variation within each species. Root diameter was measured on 20 main roots of each plant, cut within one inch from the base of the plant and mounted on scotch tape for easier handling.

All measurements were restricted...