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Climatic effects on buffelgrass productivity in the Sonoran Desert

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Abstract

Buffelgrass (*Cenchrus cilaris* L.), a perennial bunchgrass from northcentral Kenya has been successfully seeded on 400,000 ha in northwest Mexico. To determine if carrying capacity increased after buffelgrass introduction we measured live, recent-dead standing, old-dead standing and litter at 2-week intervals for three years. Live biomass was produced throughout the year but peak production, over the 3 years was in August. Peak live biomass production varied from 465 kg/ha in a summer of below-average precipitation to 3,045 kg/ha in a summer of above-average precipitation. Recent- and old-dead standing quantities were highly variable among years and transfers among components were dependent on temperature and precipitation. Buffelgrass annually produces about 3 times more green forage than native grasses.

Key Words: *Cenchurs ciliaris* L., above-ground biomass components, perennial introduced grass, northwest Mexico, hot desert, North America

In the late 1600's cattle were introduced in the Sonoran Desert of northwest Mexico, but numbers remained low until Indian raids declined in the 1800's (Hasting and Turner 1972). Since 1890, wet periods with abundant forage have been followed by overstocking, droughts and livestock reductions (Waggoner 1952). With each successive cycle, perennial grass productivity declined and northwest Mexico rangeland supported fewer livestock (Bryan 1925). Excessive and continuous grazing has been associated with the conversion of semidesert Sonoran grasslands into shrublands (Cooke and Reeves 1976).

Attempts to restore grassland productivity with native perennial grasses began in the 1950's (Cota and Johnson 1975), but plantings failed because native grass seedlings could not compete with shrubs and introduced annuals for moisture and nutrients (Cox et al. 1982). In the mid 1950's seed from African perennial grasses were introduced into northwest Mexico. One of these grasses, T-4464 buffelgrass (*Cenchrus ciliaris* L.) has been successfully seeded throughout the Sonoran Desert (Ibarra-F. et al. 1987).

It appears that the carrying capacity of rangelands in northwest Mexico increased after the introduction of T-4464 (Hanselka and Johnson 1991), but production potential needs to be measured to determine if this hypothesis is true. One of the steps in a program to evaluate carrying capacity should be to quantify the annual accumulation and decomposition characteristics of live biomass, dead standing biomass and litter in years with different weather-patterns (Weaver 1954).

Several studies have evaluated buffelgrass production (Paull and Lee 1978, Gonzales and Dodd 1979, Anning 1982, Ibarra-F. et al. 1987), but none have attempted to evaluate productivity as influenced by climate. The objective of this study was to determine how precipitation amount and distribution affected plant above-ground biomass accumulation and decomposition.

Materials and Methods

Study Site

The study site is located 82 km north of Hermosillo in northwest Sonora, Mexico (29° 41' N lat.; 115° 57' W long.) at the Carbo Livestock Research Station. Elevation is 470 m, slope is 1-2%, and soil is a Anthony fine loam (thermic Typic Torrifluvent). Soils are recent alluvium, weathered from granitic rocks, moderately basic (pH= 8.5-8.9), and depth ranges from 2 to 6 m (Hendricks 1985).

Average annual precipitation is 320 mm (Centro de Investigaciones Pecuarias del Estato de Sonora 1989). Precipitation is bimodally distributed: approximately 60% comes between July and September, and about 40% comes between October and April. May, June, and September are usually dry but exceptions do occur (Fig. 1). Summer rainfall comes as thunder-

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storms which are frequently localized and of high intensity. Daytime temperatures average 34° C, but frequently exceed 40° C in June through August. Nighttime temperatures average 8° C in winter, and may approach 0° C in either December, January, or February.

A 2.5 ha stand of dense, shrub-free buffelgrass was fenced to exclude livestock. Nine 20 by 70-m plots were established with 3 plots in each of 3 blocks. One plot in each block was randomly selected for sampling at 2-week intervals between 15 July 1985 and 1 July 1986. Three additional plots were sampled between 15 July 1986 and 1 July 1987. The remaining plots were sampled between 15 July and 1 July 1988. The Experimental design was randomized complete block with 3 replications each year.

Field Measurements

On each sampling date, 5 previously unsampled 1 by 1-m quadrats were randomly selected in each plot. Buffelgrass plants were harvested at the soil surface and litter collected from the soil surface.

Forage from 3 of the 5 quadrats in a plot was separated into live (green), recent-dead standing (yellow), and old-dead standing (gray) components. Separated and unseparated forage samples and litter were dried in a forced-draft oven at 40° C for 72 hours and weighed. Forage component dry weights from the 3 quadrats were pooled and the contribution of each to the total forage dry weight expressed as a percentage. Average component percentages were multiplied by the total forage dry weight of the unseparated quadrats. The derived dry weight component value for the 2 unseparated and the 3 separated quadrats were averaged to provide an estimate of the plot dry biomass for each forage component at each sampling date.

Precipitation was measured daily at the Carbo Livestock Research Station. Daily precipitation was summed for all dates between harvest (Fig. 1).

Statistical Analyses

The year effect was evaluated for each forage component on each sampling date using analysis of variance. When F-values were significant ($P \leq 0.05$) Least Significant Difference Tests (Steel and Torrie 1960) were used to separate means. Regression and correlation analysis were used to determine the relationship between precipitation and forage production in summer and winter.

Results and Discussion

Live Biomass

The distribution of warm- and cool-season precipitation (Fig. 1) directly influences the bimodal peaks in live biomass production

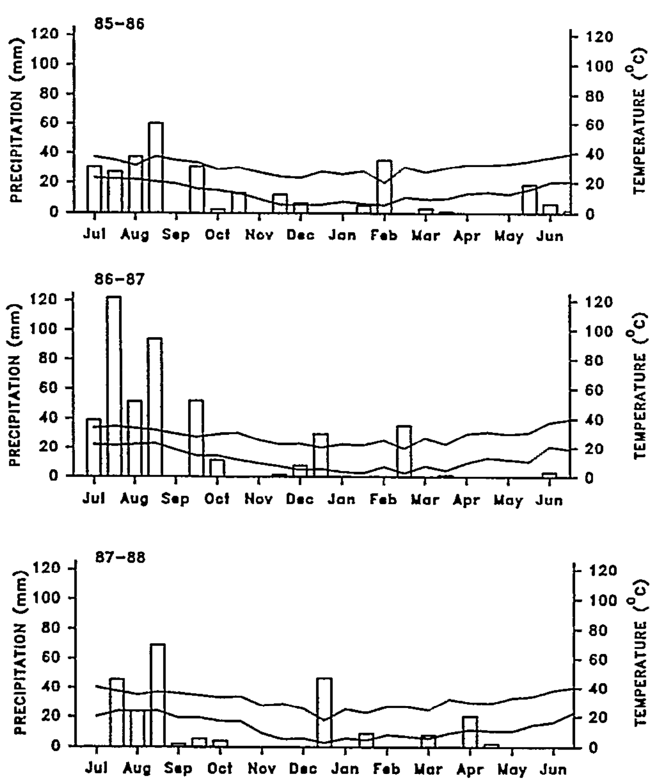

Fig. 1. Monthly precipitation (bars), mean daily maximum temperatures (upper solid line) and mean nighttime minimums (lower solid line) during 3 years at Carbo Livestock Research Station in Northwestern Mexico.

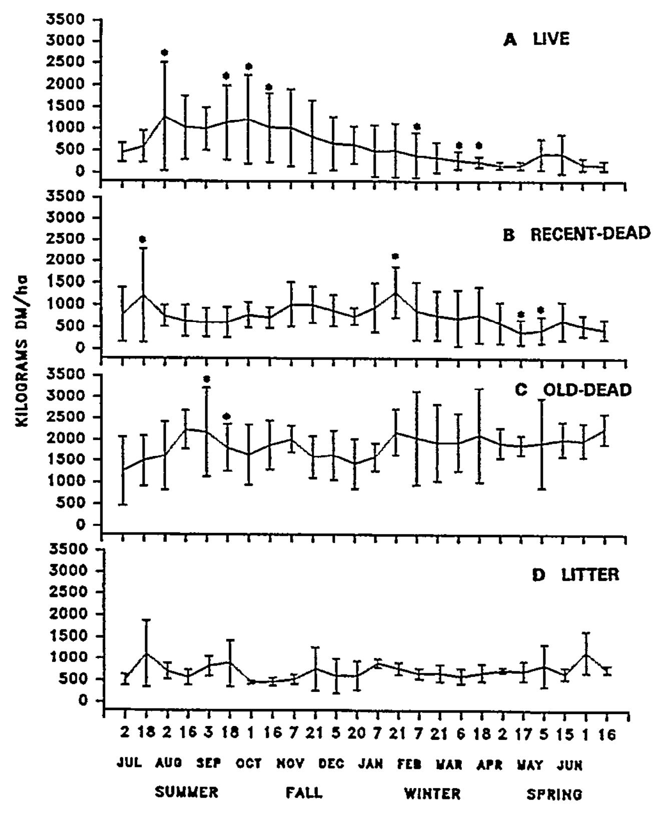

Fig. 2. Three year means and standard errors for live biomass (A), recent-dead standing biomass (B), old-dead standing biomass (C), and litter (D) of buffelgrass sampled over 3 years in Sonora, Mexico. An asterisk (*) indicates a significant difference ($P \leq 0.05$) among years at the same sampling dates. Sampling years were from 15 July 1985-1 July 1986, 15 July 1986-1 July 1987, and 15 July 1987-1 July 1988.

Table 1. Total accumulative summer or winter precipitation (mm) between 1985-88, on buffelgrass biomass (kg/ha) components.

Season	Biomass component	Regression equation	r^2
Summer	Live	Y = -1527.9 +19.8X	0.85*
	Reecent-dead	Y = - 979.0 + 5.5X	0.22 NS
	Old-dead	Y = -3299.1 + 5.1X	0.03 NS
	Litter	Y = - 716.9 + -0.1X	0.01NS
Winter	Live	Y = 1431.2 + -1.7X	0.04 NS
	Recent-dead	Y = 197.9 + 39.1X	0.30 NS
	Old-dead	Y = -1666.5 + 69.9X	0.25 NS
	Litter	Y = 1060.8 + 14.3X	0.10 NS

*Significant at $P \leq 0.05$.
NS = Not significant.

(Fig. 2-A). Live biomass was different ($P \leq 0.05$) among years on 2 summer, 2 fall and 3 winter sampling dates, and similar at remaining dates over the 3 years.

Summer (July-September) accumulative precipitation was above the long-term average (192 mm) in 1986 (358 mm), and below average in both 1985 (186 mm) and 1987 (146 mm). Peak live biomass production was greatest in 1986 (3,025 kg/ha), intermediate in 1985 (1,040 kg/ha) and least in 1987 (465 kg/ha).

Plants began to actively grow 15 days after 20 mm storms on 14 July 1985, 10 July 1986, and 28 July 1987. After initial 20 mm storms, culms elongated in 20 days, leaves elongated in 25 to 27 days and seedheads were present in 30 days. Green leaves produced at the plant base grew horizontally and were protected by recent-and old-dead standing biomass. Most summer leaves became dormant in fall and winter but a few leaves remain green throughout the year. Following fall, winter, and spring moisture, green leaves emerge at the crown base but leaves elongate only when minimum temperatures approach 15° C (Cox et al. 1988).

Observations made during this 3 year study suggest that buffelgrass initiates leaf production whenever soil moisture is available and minimum temperatures exceed 15° C. When more than 150 mm of precipitation was recorded in summer (Fig. 1), live biomass exceeded 1,000 kg/ha (Fig. 2-A). When summer precipitation was less than 150 mm live biomass approached 500 kg/ha.

In northwest Mexico precipitation is bimodally distributed, and summer precipitation has the greatest effect on plant growth (Table 1). The coefficient of determination between accumulative summer precipitation and summer buffelgrass growth ($r^2 = 0.85$) is 20% greater than that reported for other warm-season African grasses (Cox et al. 1990) and native grasses (Cable 1975) in Arizona. Hence about 80% of the summer growth of buffelgrass can be accounted for by accumulating the July to September precipitation. The lack of correlation between winter precipitation and winter growth is because winter temperatures of 5°C or less limit leaf growth (Cox et al. 1988).

Recent-Dead Standing

Recent-dead biomass was different ($P \leq 0.05$) among years on 1 summer, 1 winter and 2 spring sampling dates, and similar on remaining dates over the 3 years (Fig. 2-B). Recent-dead generally increased in summer, decreased in fall, increased in winter and decreased in spring.

Recent-dead accumulations in summer and winter were highly variable and the rate of transfer to old-dead standing was dependent on the presence or absence of precipitation. With each successive July and August storm, recent-dead weathered and transferred to old-dead. In summer, the recent-to old-dead transfer may occur in as few as 20 days (1986) on as many as 35 days (1987). Immediately following precipitation in February 1986 and 1987, and December 1987, we observed a rapid recent-dead to old-dead transfer and a winter greenup (Fig. 2). The recent- to old-dead transfer occurred in 15 days during the mild spring of 1986, and in 30 days during the cool spring of 1987.

Old-Dead Standing

Old-dead biomass was different ($P \leq 0.05$) at 2 summer sampling dates, and similar at all remaining dates over the 3 years (Fig. 2-C). Unusually low quantities in summer and fall 1985 were related to livestock activities prior to fencing, and rapid transfer from old-dead to litter occurred during the atypically wet summer of 1987. During the atypically wet summer, we observed termites (*Gnathamitermes perplexus*) harvesting old-dead standing in native grass stands, we did not observe termite activity in buffelgrass stands. Buffelgrass seed stalks may contain more lignin than native grass seed stalks.

Litter

Litter quantities were similar ($P \leq 0.05$) at all sampling dates over the 3 years (Fig. 2-D). Litter amounts in summer of 1985 exceeded those in other years because old culms dislodged by cattle prior to fencing accumulated on the soil surface after summer thunderstorm activity.

Litter quantities generally peaked in spring and summer, and disappeared in fall and winter. Observations suggest that spring winds dislodge dead leaves and culms, and summer rains move leaf and culm fragments from open areas between plants to areas beneath buffelgrass canopies. Litter accumulations beneath plant canopies may serve as a nitrogen reserve which becomes available to forbs in late winter and to perennial grasses in summer (Cox et al. 1984).

Management Implications

Above-ground net primary production (ANP) of buffelgrass was 7,025 kg/ha in south Texas (Gonzales and Dodd 1979, Hanselka and Johnson 1991), ranged from 3,000 to 7,000 kg/ha in Queensland, Australia (Paull and Lee 1978), and averaged 6,950 kg/ha during the 3 years of this study. ANP of 10 North America ungrazed temperate grasslands averaged 2,350 kg/ha, and ranged from 540 to 5,230 kg/ha (Sims and Singh 1978). At selected sites in northwest Mexico and south Texas, buffelgrass production is about 25% greater than the most productive grasslands in North America.

In the Sonoran Desert, livestock carrying capacity varies from 27 to 40 ha/AUY (animal unit year) on native range, from 9 to 15 ha/AUY on planted buffelgrass pasture, and from 3 to 4 ha/AUY on combinations of native range and buffelgrass pasture (Ibarra-F. and Cox 1988, Martin-R. 1989). In pastures where buffelgrass occurs with native forbs, grasses and shrubs we observed livestock grazing shrubs in winter and spring, forbs and buffelgrass leaves in spring, buffelgrass in summer, and buffelgrass and shrubs in fall. This seasonal pattern of animal selectivity may explain why livestock productivity increased when buffelgrass plantings were strategically located in native rangeland pastures.

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