Grazing Effects on Water Relations of Caucasian Bluestem

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Abstract

Caucasian bluestem [*Bothriochloa caucasica* (Trin.) C.E. Hubb.] is a warm-season grass introduced from Eurasia that is currently used for reseeding rangelands in the southern Great Plains. Although this species is thought to be grazing tolerant, no specific information is available concerning its response to grazing. This study was conducted to evaluate the effect of 2 levels of grazing on xylem water potential (ψ) and total leaf conductance (gT) of Caucasian bluestem. During the grazing period (mid May to mid September) diurnal ψ and gT measurements were made on 3 days in 1983 and 1984, and afternoon measurements were taken at weekly intervals in 1984. Soil moisture at 15, 45, and 75 cm depths was monitored in 1984. Heavily grazed plants exhibited consistently higher (less negative) ψ, and generally higher gT than lightly grazed plants. Averaged over the season, heavy grazing increased mean afternoon ψ and gT by 28 and 76%, respectively, compared to light grazing. Soil moisture was conserved with heavy grazing; treatment differences were greatest during July, which is generally the driest summer month in central Oklahoma. Thus, for Caucasian bluestem, leaves from heavily grazed swards were under less water stress than leaves from lightly grazed swards.

Key Words: *Bothriochloa caucasica*, stomatal conductance, xylem potential, soil moisture

In recent years Old World bluestems (*Bothriochloa* spp.) have gained popularity for use in forage/livestock systems in the Southern Great Plains. These native Eurasian species tend to increase under heavy grazing and other disturbances (Harlan et al. 1958). However, responses of Old World bluestems to defoliation have been studied with clipping (e.g., Anderson and Matches 1983, Coyne and Bradford 1985) rather than grazing. Hodgkinson (1980) and Briske and Stuth (1982) have indicated that grazing patterns are seldom adequately characterized, and such information is necessary if grazing is to be simulated. Because grazing patterns are difficult to reproduce, Hodgkinson (1980) concluded that future studies should examine physiological stress in plants subject to actual grazing and growing in natural communities.

Water stress is critical to plant growth and survival, particularly in regions subject to periodic drought. Leaf expansion is sensitive to even mild water stress, and in many species is completely curtailed with moderate water stress (Hsiao and Acevedo 1974). If leaf area removal by grazing influences water relations, growth would also be affected. The objectives of this study were to determine the effect of continuous heavy and light grazing on xylem pressure potential, total leaf conductance, and soil moisture in swards of Caucasian bluestem (*Bothriochloa caucasica* (Trin.) C.E. Hubb.).

Materials and Methods

The study was conducted during 1983–1984 at the USDA Forage and Livestock Research Laboratory, near El Reno, Okla. Soils at the study site were fine-silty Pachic Haplustolls of the Dale Series. Annual precipitation averaged 76.2 cm from 1977–1984. Precipitation was above average in 1983 (99.0 cm) and slightly below average in 1984 (72.4 cm).

We used a sward of Caucasian bluestem which had been seeded in 1979 and hayed or leniently grazed prior to initiation of this study. Continuous variable (put-and-take) stocking was used to maintain high herbage mass (light grazing) and low herbage mass (heavy grazing) treatments on 1-ha pastures (see Wheeler et al. (1973) for discussion of variable stocking). Steers averaging about 225 kg were put on the pastures mid-May and grazed until late September of both years. Pastures were characterized by measuring herbage mass and sward height twice a month, and leaf area index about monthly (Table 1). Herbage mass was estimated with a pasture meter (Electrical Equipment Limited, Armcliffe, N.S.W., Australia)[1], which was calibrated using double sampling with 8

[1]Mention of a trade name does not indicate endorsement by USDA.

Table 1. Descriptions of heavily (H) and lightly (L) grazed Caucasian bluestem pastures.

	1983		1984	
	H	L	H	L
Seasonal range in herbage mass (kg/ha)	860–1530	3180–5375	1037–1952	6516–10,100
Sward height (cm)	5–10	20–25	5–10	35–45
Range in number of steers per hectare	3.0–8.00	2.5–4.5	3.0–7.0	2.5–4.2
Leaf area index	0.7–1.0	1.4–3.2	0.4–1.0	1.4–4.5

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clipped plots per treatment per sampling date. Sixty measurements per pasture were taken for both herbage mass and sward height at each sampling date. Leaf area index was measured by clipping four 15 × 25-cm quadrats per pasture, separating green leaves and scanning them with a leaf area meter (LI-3000, Li-Cor, Inc., Lincoln, Neb.).

Two teams, each equipped with a pressure chamber (3000 Series, Soilmoisture Equip. Corp., Santa Barbara, Calif.) and porometer (LI-700, Li-Cor, Inc., Lincoln, Neb.) conducted the water relations measurements. Paired samples in the heavily and lightly grazed treatments were taken simultaneously to avoid any affect short-term environmental fluctuations might have on treatment comparisons. Teams were alternated between treatments so that equipment or operator bias also would not affect treatment comparisons. We used fully expanded leaf blades from the upper canopy. Total leaf conductance (gT) was the sum of adaxial and abaxial conductances from the transient porometer. After conductance was measured, the leaf blade was wrapped in moist paper toweling, excised, and xylem water potential (ψ) taken with a pressure chamber. Diurnal trends in ψ and gT were monitored on 3 dates in both 1983 and 1984. On each date, predawn ψ was measured, and during daylight hours ψ and gT were measured 4 times. At about weekly intervals from 14 June to 9 September 1984, ψ and gT were measured between 1300 and 1430 hr. At each sampling time ambient temperature and relative humidity were measured with a sling psychrometer, and photosynthetically active radiation integrated over a 100 s period prior to sampling with a quantum sensor (LI-183, Li-Cor, Lincoln, Neb.).

Sample leaves were selected at random from paired (parallel) 5 × 5-m macroplots located along the fenceline separating the pastures. There were 4 sets of macroplots (thus 4 per treatment) located at about 20-m intervals. At each sampling time 1 sample per macroplot was measured for ψ and gT. Soil moisture was monitored at about 10-day intervals during 1984 with gypsum blocks (5200 Series Soilmoisture Equip. Corp., Santa Barbara, Calif.) buried at 15, 45, and 75 cm within each macroplot.

Data for gT and ψ were analyzed using analysis of variance with grazing treatment and time of day or date as main effects. Predawn ψ was analyzed separately from daytime ψ values using paired-*t* tests. Treatment differences in soil moisture were analyzed with pair-*t* tests for each date and depth within date.

Results and Discussion

Leaves sampled during the day from the heavily grazed pasture were generally under less water stress (less negative ψ) and had higher gT than leaves from the lightly grazed pastures (Figs. 1, 2 and 3). Predawn ψ measurements showed no treatment effects except on 27 September 1983, when values were less negative on the heavily grazed pasture. Presumably roots in the lightly grazed pasture extracted enough water to rehydrate leaf tissue at night, but could not provide enough moisture for transpiration demand during the day. Wolf and Parrish (1982) found that clipping tall fescue *(Festuca arundinacea)* leaves improved ψ in remaining plant parts and thereby accelerated cell expansion. They stated that removal of transpiring leaf area overcame growth limitations imposed by an inadequate root system and/or low soil moisture. Jackson (1974) studied swards of perennial ryegrass *(Lolium perenne)* and found that cutting reduced water stress and increased stomatal conductance under nonirrigated conditions. In contrast, Nowak and Caldwell (1984) found no improvement ψ of similarly aged foliage elements on clipped and unclipped bunchgrasses.

Plant water status is important in that leaf expansion and thus vegetative growth are severely inhibited by moderate water stress (Kramer 1983). Leaf expansion tends to be more sensitive to water stress than is CO_2 assimilation; thus dry matter may be reduced by water deficits that are not severe enough to limit stomatal opening and photosynthesis (Hsiao and Acevedo 1974). In many cases a decrease in ψ of 0.3 to 0.4 MPa relative to well-watered conditions

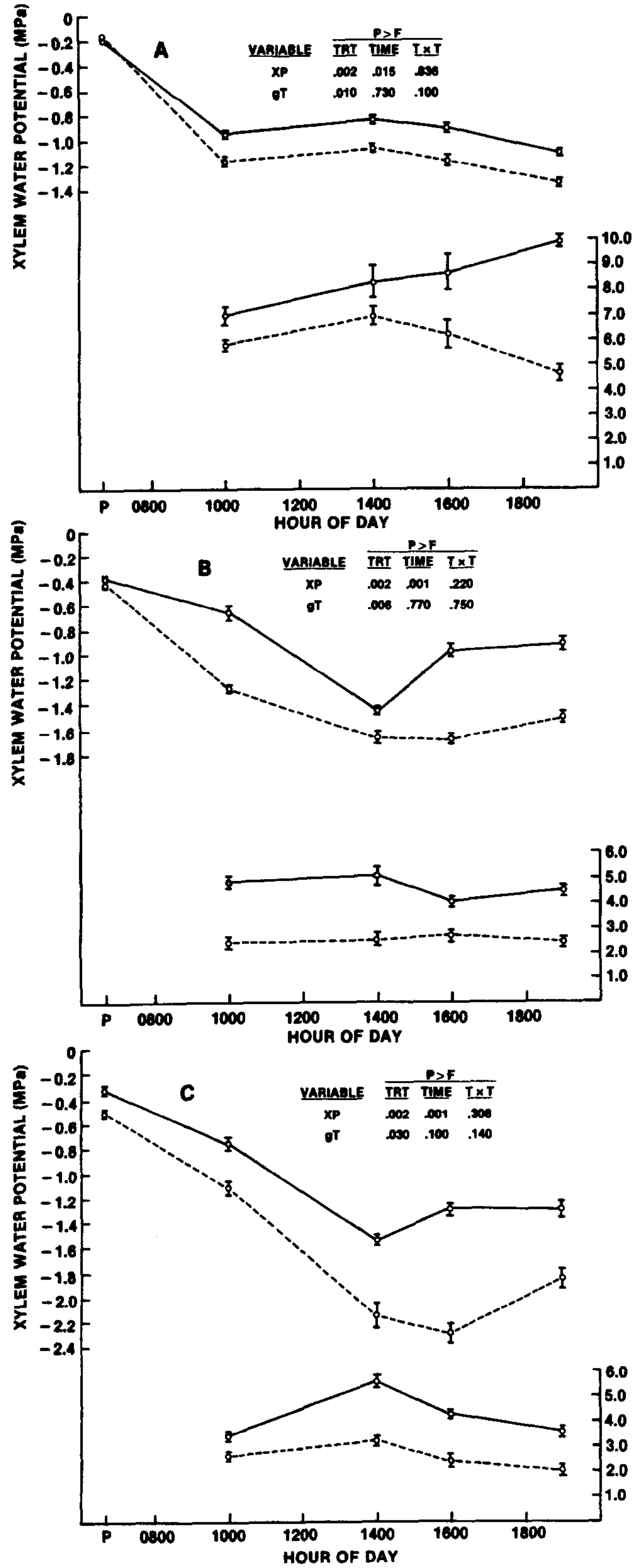

Fig. 1. *Diurnal trends in xylem water potential (XP) and total leaf conductance (gT) for heavily (solid lines) and lightly (dashed lines) grazed Caucasian bluestem in 1983. Dates are as follows: A = July 6, B = July 25, and C = September 27. Probability statements of treatment and time effects and their interaction appear at the top of each graph (predawn (P) values are not included in the analysis). Vertical lines represent 1 standard error of the mean (n = 4).*

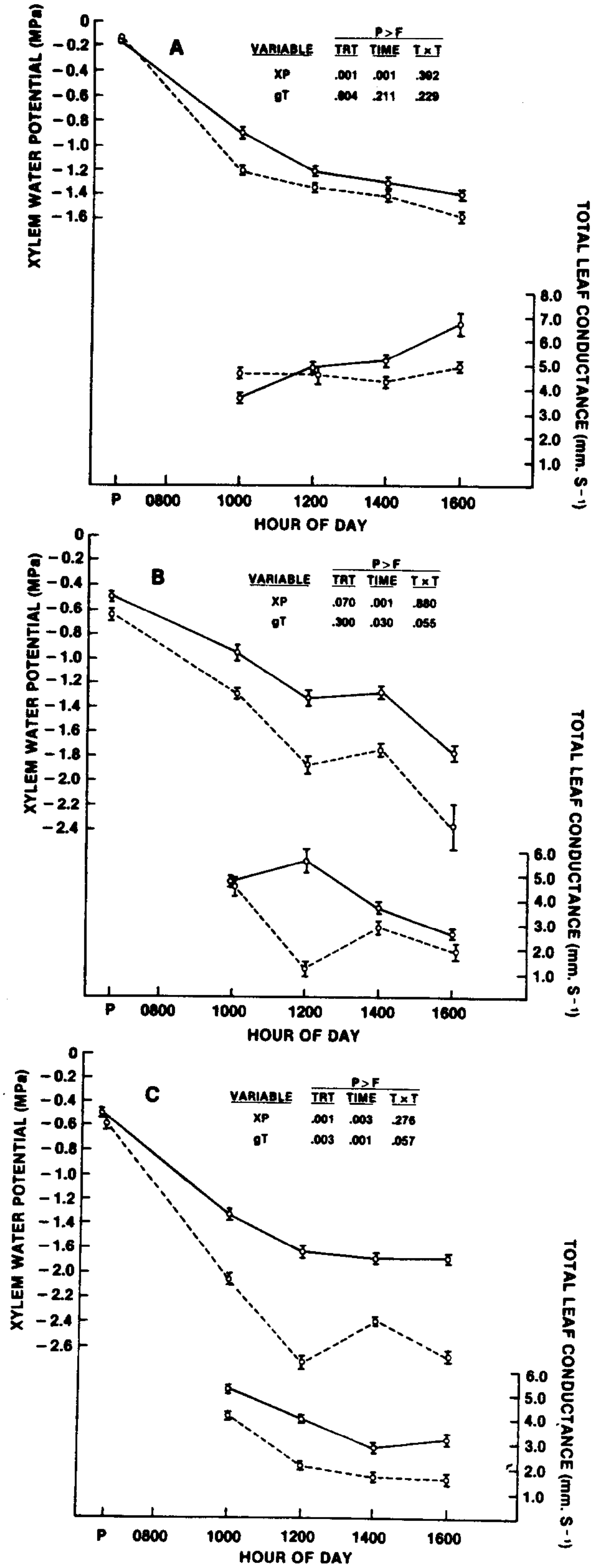

Fig. 2. *Diurnal trends in xylem water potential (XP) and total leaf conductance (gT) for heavily (solid lines) and lightly (dashed lines) grazed Caucasian bluestem in 1984. Dates are as follows: A = June 16, B = July 17, and C = August 16. Probability statements for treatment and time effects and their interaction appear at the top of each graph (predawn (P) values are not included in the analysis). Vertical lines represent 1 standard error of the mean (n = 4).*

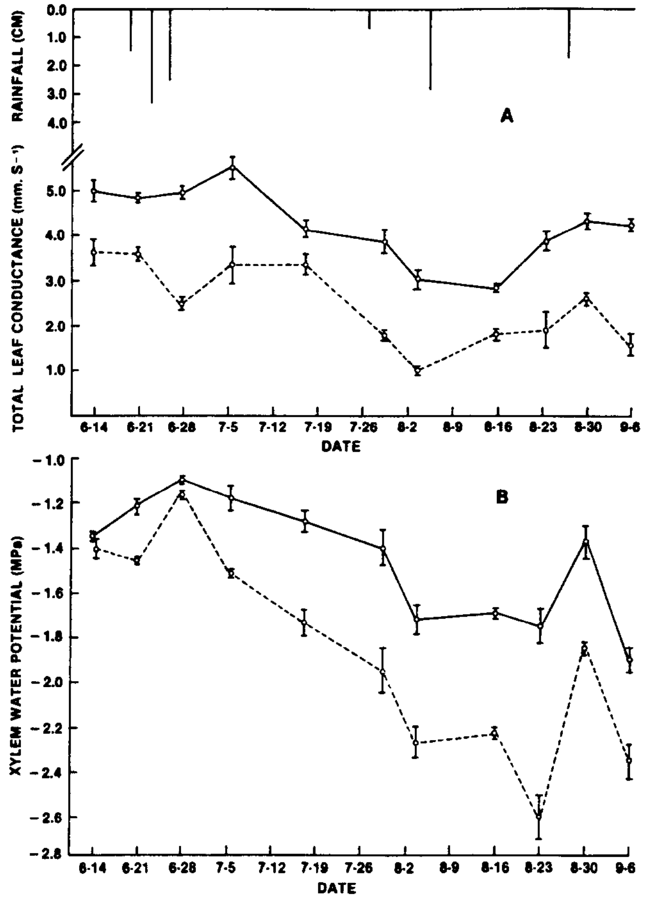

Fig. 3. *Seasonal trends in total leaf conductance (A) and xylem water potential (B) for heavily (solid lines) and lightly (dashed lines) grazed Caucasian bluestem. Measurements were taken between 1300 and 1430 hrs on each measurement date. During sampling, ambient temperature ranged from 34–39° C, relative humidity from 40–55% and photosynthetically active radiation from 1,800–2,000 µmoles m^{-2} S^{-1}. Rainfall events are presented at the top. Veritical lines around each point are 1 standard error of the mean (n = 4).*

is sufficient to stop cell enlargement entirely (Hsiao et al. 1976). In this study, level of herbage removal had a major impact on water stress. During July and August of 1984, afternoon ψ was 0.3 to 0.9 MPa less negative in the heavily grazed than in the lightly grazed pasture (Fig. 3), and similar differences were noted in the diurnal measurements (Figs. 1 and 2).

In addition to reduced water stress on the heavily grazed pasture, there was an increase in stomatal conductance relative to the lightly grazed pasture. This is consistent with the results of several defoliation studies (Gifford and Marshall 1973, Deinum 1976, Detling and Painter 1983, Heichel and Turner 1983). The importance of gT in regulating photosynthesis will depend on the relative contribution of stomatal and mesophyll resistances to total CO_2 flux resistance. In warm-season grasses, stomatal resistance tends to dominate the total resistance to CO_2 flux (Boyer 1970, Ludlow and Wilson 1971, McPherson and Slayter 1973, Gifford 1974), especially at the higher temperatures that are optimum for this group of grasses (e.g., Coyne et al. 1982). At full sunlight and 35° C ambient temperature, Coyne and Bradford (1984) found that stomatal resistance of Caucasian bluestem accounted for 70% of the total resistance to CO_2 flux. In our study, the overall mean gT for the 1984 afternoon measurements (Fig. 3) was 2.52 mm s^{-1} and 4.44 mm s^{-1} for lightly and heavily grazed plants, respectively. A 76% increase in gT would likely result in increased photosynthetic rate per unit leaf area. However, the increase in gT was less than the

Table 2. Soil moisture tension (MPa) on heavily (H) and lightly (L) grazed Caucasian bluestem pastures during 1984[1].

		Date								
Grazing Trt	Depth (cm)	6/15	6/26	7/9	7/18	7/30	8/7	8/23	8/30	9/11
	15	–0.02	–0.02	–0.13	–1.5	–1.5	–0.08*	–1.5	–0.5	–1.5
H	45	–0.02	–0.02	–0.02	–0.04*	–0.25	–0.5	–1.5	–1.5	–1.5
	75	–0.02	–0.02	–0.02	–0.02*	–0.04*	–0.07	–0.3	–0.6	–1.5
	15	–0.02	–0.02	–0.18	–1.5	–1.5	–1.3	–1.5	–1.5	–1.5
L	45	–0.02	–0.03	–0.04	–0.25	–1.5	–1.5	–1.5	–1.5	–1.5
	75	–0.03	–0.03	–0.04	–0.14	–0.9	–1.5	–1.5	–1.5	–1.5
Rainfall Received During each Interval (cm)			7.34	0.08	0.00	0.64	2.95	0.41	1.73	0.20

[1]An asterick indicates that treatments were significantly different ($P<0.05$) at that particular date and depth.

reduction in leaf area attributable to heavy grazing (Table 1). Thus on a whole canopy basis CO_2 uptake was probably greater on the lightly grazed pasture.

In general, our results support McNaughton's (1983) contention that herbivory can improve water relations of leaf tissue. He suggests that the improved water relations result from a greater ratio of absorbing root surface to transpiring leaf area. In addition, the reduction in transpiring leaf surface may conserve soil water, thus sustaining plant growth over a longer period (McNaughton 1983). Indeed we did find that soil moisture declined more slowly on the heavily grazed pasture than on the lightly grazed pasture (Table 2). The difference between treatments was most obvious during July, which is typically the driest summer month in central Oklahoma. Thus, in the case of Caucasian bluestem, there were several potentially beneficial effects of heavy grazing: (1) water stress was reduced; (2) stomatal conductance was increased; and (3) soil moisture was conserved.

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