Cane Bluestems: Forage Yield, Forage Quality, and Water-Use Efficiency

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Highlight: Three collections of cane bluestem (*Bothriochloa barbinodis* Herter) were evaluated under three water and three harvest regimes. Dry matter yields, under natural rainfall and irrigation, averaged 3.8 and 8.7 metric tons/ha, respectively. Productivity of the three collections ranked G-866 > G-820 > PMT-333 under natural rainfall, but with irrigation, the ranking was G-820 > G-866 > PMT-333. One and two harvests per season resulted in near-equal yields, but three harvests decreased yields. Cane-bluestem forage contained about 10% protein and 0.22% phosphorus (P) in mid-June. In November, previously unclipped forage contained 4.4% protein and 0.12% P, while that clipped twice contained 7.3% protein and 0.18% P.

Yield and quality of cane bluestem compared favorably with that of switchgrass (*Panicum virgatum* L.) grown in a similar study. Maximum production was obtained with about 77 cm of water use (rainfall + irrigation + soil water).

Cane bluestem (*Bothriochloa barbinodis* Herter) is a coarse warm-season grass similar to silver bluestem (*B. saccharoides* (Swartz) Rydl.). It occurs from Oklahoma to Arizona and Texas, and south into Mexico. It grows on mesas, sandy slopes, open grounds, in gullies, and along the banks of dry washes, but usually occurs scatteringly and seldom forms dense stands (Hitchcock 1950). Gould (1951) has observed it to be extremely drought resistant and well adapted to southwestern ranges.

Humphrey (1960) classified cane bluestem as fair forage because it is coarse and nutrients tend to leach from forage when plants are dry. Gay and Dwyer (1965) considered it fair-to-good forage for cattle and sheep. Fudge and Fraps (1945) found that cane bluestem contained more crude protein and phosphoric acid than did silver bluestem. Fraps and Cory (1940) reported that crude protein and phosphoric acid concentrations of silver bluestem were fair in June and July, but crude protein concentrations were deficient and phosphoric acid concentrations were very deficient in November. In Arizona (Humphrey 1960), and in New Mexico (Gay and Dwyer 1965), cane bluestem and silver bluestem are considered as having similar forage values.

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The search for better-adapted, more productive grass is continuous. During the drought of the 1950's the Texas Agricultural Experiment Station and the Soil Conservation Service collected promising grass species from throughout the southwestern United States and northern Mexico. These collections, many of which were cane bluestems, were grown in a nursery at the U.S. Big Spring Field Station, Big Spring, Tex. The objectives of this study were to determine the forage yield and quality potential of three of the more promising cane bluestem collections.

Methods and Materials

The study was conducted on Amarillo fine sandy loam, an Aridic Paleustalls of the fine-loamy, mixed thermic family. The soil has been described in detail by Burnett et al. (1962). At Big Spring, the 74-year average preseasonal precipitation (November-March) and seasonal precipitation (April-October) are 9.7 and 37.1 cm, respectively. The average growing season is 222 days.

The three selections of cane bluestems were: G-866 (collected between Saltillo and Torreon, Mexico), G-820 (collected on a mountain-top between Durango and Mazatlan, Mexico), and PMT-333 (collected near Van Horn, Texas).

Three water regimes and three harvest regimes were applied in a 4-year study. Water variables occupied main plots; bluestem collections occupied subplots; and harvest variables occupied sub-subplots in a split-split-plot design with three replications. Main plots, 8.5 by 12.8 m, were leveled and bordered to contain all precipitation and irrigation water. In 1969, greenhouse-grown seedlings were transplanted into 4-row plots at 50- by50-cm spacings. Data were collected from the 2-center rows.

Water regimes were: W_1 (precipitation only), W_2 and W_3 (10 and 20 cm of water, respectively, applied when 20 cm of water had been depleted from the upper 180 cm of the soil profile). Soil water was measured monthly, using the neutron scattering technique, at 20-cm increments to a 360-cm depth. Growing season precipitation, irrigation water applied, soil water depletion, and total water use are presented in Table 1. Growing season precipitation was near average in 1973, and above the long-time average in the other seasons. The high negative soil water depletion (accretion) in1974 resulted from the seasonal rainfall coming too late for utilization by the grasses. The three harvesting treatments were: H_1 (one clipping in November); H_2 (two clippings in mid-July and November); and H_3 (three clippings in June, August, and November). At the first clippings of H_2 and H_3, and the single clipping of H_1, half of the growth was removed. Subsequent clippings of the H_2 and H_3 treatments were at the heights of the initial clippings. Forage samples were oven-dried at 65°C, and forage yields are reported on the oven-dried basis.

Table 1. Growing season precipitation (cm), irrigation (cm), soil water depletion (cm), and seasonal water use (cm) by cane bluestems under three water regimes.

Year	Water input	Water regime W_1	W_2	W_3
1971	Precipitation	43.7	43.7	43.7
	Irrigation	0.0	40.0	80.0
	Soil water depletion[1]	6.8	−10.3	−14.0
	Total water use	50.5	73.4	109.7
1972	Precipitation	44.3	44.3	44.3
	Irrigation	0.0	52.0	83.0
	Soil water depletion[1]	5.6	2.3	−1.1
	Total water use	49.9	98.6	126.2
1973	Precipitation	37.7	37.7	37.7
	Irrigation	0.0	20.0	40.0
	Soil water depletion[1]	21.7	21.8	22.1
	Total water use	59.4	79.6	99.8
1974	Precipitation	48.7	48.7	48.7
	Irrigation	0.0	30.0	60.0
	Soil water depletion[1]	−25.3	−23.3	−25.5
	Total water use	23.4	55.4	83.2
Average annual water use		45.8	76.8	104.7

[1]Total soil water to 360 cm in March less that present in November.

Total nitrogen (N) was determined by the Kjeldahl method (modified to include nitrate) and multiplied by 6.25 to estimate crude protein (protein). Forage was wet-ashed (Wolf 1944) and total phosphorus (P) was determined colorimetrically (Watanabe and Olsen 1965). Average protein and P concentrations listed in tables and reported in the text were calculated from forage, protein, and P yields.

Soil tests were made each year and fertilizer was applied to obtain vigorous plants and good grass growth. In 1969, 1970, and 1971, 16-20-0 fertilizer was applied. Rates of N and P_2O_5 were, respectively, 100 and 125 kg/ha in 1969, and 200 and 250 kg/ha in 1970 and 1971. In 1972 and 1973, since soil tests indicated that only N was required, ammonium nitrate was applied at 200 kg N/ha. No fertilizer was applied in 1974. Fertilizer was applied in a single spring application in 1969. In later years, half the fertilizer was applied in April or May, and the other in July.

Results and Discussion

Forage Yield

Average annual yields were 8.6, 6.7, and 5.9 metric tons/ha (tons/ha) for the three selections, G-820, G-866, and PMT-333, respectively, (Table 2). Without irrigation, G-866 and G-820 outyielded PMT-333. However, under both irrigation treatments, G-820 outyielded both G-866 and PMT-333. Average annual forage yields on the lower irrigation level were twice those on the unirrigated treatment and equal to those on the higher irrigation level. The cane bluestems responded to moderate levels of irrigation but additional water did not further increase yields. Two harvests per season gave almost as much forage as a single harvest, while yields tended to decrease when plants were clipped three times.

Yields from the first harvests of all three harvest regimes (Table 3) showed that, regardless of water treatments, the three selections made about 20% of their seasonal growth by mid-June; 30% between mid-June and mid-July; and 50% after mid-July. When harvested in July and November, unirrigated treatments produced about 40% and irrigated treatments produced about 50% of their seasonal growth by mid-July. When harvested in June, August, and November, unirrigated treatments made about 20% of their seasonal growth by the June harvest; 40% between the June and August harvests; and 40% after the August harvest. With irrigation, proportions of seasonal growth during the respective periods were 25, 62, and 13%. As compared to irrigated conditions, bluestems grown under natural rainfall made a higher proportion of their seasonal growth and made more total growth late in the season (irrigated: 1.0 tons/ha; unirrigated: 1.5 tons/ha). Thus, when water was adequate, cane bluestem grew most between mid-June and late August. If water was not available at that time but was available later, they grew more later in the season. This flexibility in growth patterns should be considered in management of the cane bluestems and in evaluation of their potential.

Forage Quality

Forage of the cane bluestem selections contained about 10% protein and 0.22% P in mid-June. At the end of the season, protein levels had declined to 4.4% in H_1 and to 7.3% in H_3. Phosphorus concentrations had declined to 0.12 and 0.18% on H_1 and H_3, respectively (Table 3). Of the three variables studied (selections, water regimes, and harvest regimes), harvest regimes had greatest effects on protein and P concentrations. Both protein and phosphorus concentrations were inversely related to the age of the forage. Three cuttings per season produced 6.1 tons/ha of forage containing 8.3% protein and 0.16% P; two cuttings produced 7.4 tons/ha of forage containing 7.0% protein and 0.17% P; and a single harvest produced 7.8 tons/ha of forage containing 4.4% protein and 0.12% P.

Forage protein levels were inversely related to the amounts of water applied. Also, P was slightly higher on the dry treatment than on the watered treatments. The dry treatment produced 3.8 tons/ha of forage that contained 7.39% protein and 0.16% P; the intermediate treatment produced 8.8 tons/ha of forage that contained 6.49% protein and 0.16% P; and the wettest treatment produced 8.6 tons/ha of forage that contained 5.97% protein and 0.15% P. The reduced levels of protein and P with the

Table 2. Forage yields (metric tons/ha) and forage protein and phosphorus contents (%) of three cane bluestem selections under three water levels and three harvest regimes, 1971–1974.

Treatment	G-366 Yield	G-366 Protein	G-366 Phosphorus	G-820 Yield	G-820 Protein	G-820 Phosphorus	PMT×333 Yield	PMT×333 Protein	PMT×333 Phosphorus
Water levels									
W_1	4.6 c[1]	7.72	.164	4.1 c	7.13	.175	2.8 d	7.19	.142
W_2	8.0 b	6.53	.148	10.9 a	6.58	.167	7.3 b	6.30	.148
W_3	7.5 b	6.02	.144	10.8 a	5.96	.158	7.6 b	5.92	.149
Harvest regimes									
H_1	6.8 c	4.58	.109	10.3 a	4.44	.129	6.4 c	4.27	.108
H_2	7.0 c	6.96	.159	8.6 b	7.23	.178	6.2 cd	6.84	.160
H_3	6.2 cd	8.45	.185	6.8 c	8.34	.201	5.0 d	8.14	.182
Mean	6.7 B[1]	6.61	.150	8.6 A	6.41	.164	5.9 C	6.27	.147

[1] Values followed by the same letter are not significantly different at the 5% probability level. Small letters are used for means of individual treatments and capital letters for overall means of selection.

Table 3. Mean forage yields (metric tons/ha) and forage protein and phosphorus contents (%) of three cane bluestem selections at harvest dates under three harvest regimes (H) and three water levels (W), 1971–1974.

Harvest regime and month	W_1 Yield	W_1 Protein	W_1 Phosphorus	W_2 Yield	W_2 Protein	W_2 Phosphorus	W_3 Yield	W_3 Protein	W_3 Phosphorus	Mean Yield	Mean Protein	Mean Phosphorus
H_1												
Nov.	3.6 d[1]	5.60	.131	9.8 a	4.42	.116	10.1 a	4.03	.114	7.8 A[1]	4.43	.117
H_2												
July	1.7	8.87	.188	4.8	8.89	.215	4.5	7.65	.183	3.7	8.38	.198
Nov.	2.6	6.36	.147	4.5	5.62	.131	4.0	5.34	.136	3.7	5.69	.137
Total	4.2 d	7.34	.163	9.3 ab	7.31	.175	8.4 b	6.56	.161	7.4 A	7.03	.167
H_3												
June	0.6	12.42	.225	1.8	9.19	.208	1.7	9.63	.217	1.4	9.85	.214
Aug.	1.4	10.34	.209	4.4	7.86	.181	4.6	7.53	.183	3.5	8.05	.186
Nov.	1.5	7.00	.171	1.0	8.16	.178	1.0	7.05	.180	1.2	7.35	.177
Total	3.6 d	9.23	.195	7.2 c	8.23	.187	7.3 c	7.96	.191	6.1 B	8.32	.158
Mean	3.8 B	7.39	.163	8.8 A	6.49	.156	8.6 A	5.97	.151			

[1] Values followed by the same letter are not significantly different at the 5% probability level. Small letters are used for means of individual treatments and capital letters for overall means.

higher water regimes were probably caused by the diluting effect of increased growth. The reduction in protein level between W_2 and W_3 was not associated with increased growth. Possibly, the extra water of the W_3 treatment leached some of the applied N below the root zone.

Selection G-866 had the highest protein concentration, and G-820 had the highest P concentration (Table 2). Selection G-866 produced 6.7 tons/ha of forage that contained 6.6% protein and 0.15% P; G-820 produced 8.6 tons/ha of forage that contained 6.4% protein and 0.16% P; and PMT-333 produced 5.9 tons/ha of forage containing 6.3% protein and 0.15% P.

Minimum requirements for beef cows nursing calves (National Research Council 1970) are 9.2% protein and 0.22% P. The protein requirement for nursing cows would be adequate if the three cane bluestem selections were harvested in June. Phosphorus levels were almost adequate at the June harvest and decreased as the season progressed. Protein and P levels in November-harvested forage from the H_1 and H_2 harvest regimes did not meet minimum requirements for dry cows. Thus, supplements would be needed for fall and winter utilization of cane bluestem.

Water Use and Water-Use Efficiency

Water use data are given in Table 1 and water-use efficiencies are presented in Table 4. The three cane bluestem selections had similar total water use. Thus within water regimes, water-use efficiencies were proportional to forage yields, and the three selections had the same ranking in water-use efficiency as in yield. Highest water-use efficiencies were obtained under the intermediate water level. Those for W_1 and W_3 were similar but lower. Because the extra 10 cm of water/irrigation applied in W_3 (as compared with W_2) did not increase yields, we concluded that 10-cm irrigations were sufficient and that the additional water was excess to the needs of the plants. If the timing of irrigation was satisfactory to keep plants growing rapidly, then the average annual water use on W_2 (76.8 cm) was sufficient for maximum yields of these cane bluestems under the uniform fertility imposed.

One or two clippings per year (H_1 and H_2) allowed similar water-use efficiencies, but three clippings per year (H_3) reduced efficiencies relative to the other two harvest treatments. the reduction in efficiency on H_3 was due to reduced yield rather than to increased water use.

Table 4. Water-use efficiency (kg/ha/cm) of three cane bluestem selections under three water levels and three harvest regimes, 1971–1974.

	G-866	G-820	PMT-333	Mean
Water levels				
W_1	96.2 b[1]	87.0 b	55.3 d	79.5 B
W_2	103.2 b	143.5 a	94.3 b	113.7 A
W_3	71.3 c	101.7 b	72.8 c	81.9 B
Harvest regimes				
H_1	86.2 bc	124.5 a	75.7 cd	95.5 A
H_2	97.0 b	119.2 a	81.4 bc	99.2 A
H_3	87.4 bc	88.5 bc	65.4 d	80.4 B
Mean	90.2 B	110.7 A	74.1 C	91.7

[1] Averages followed by the same lower case letter are not significantly different at the 5% probability level. Small letters are used for means of individual treatments and capital letters for overall means.

Comparison with Switchgrass

Both the yield and quality of the cane bluestems compared favorably with those of switchgrass (*Panicum virgatum* L.) grown in a similar experiment at Big Spring. Without irrigation, the highest yielding switchgrass selection (G-300) produced 2.7 tons/ha of forage containing 7.8% protein and 0.18% P; and with full irrigation (W_3), it produced 8.2 tons/ha of forage containing 7.4% protein and 0.17% P (Koshi et al. 1977). In this study, without irrigation, cane bluestem collection G-820 produced 4.1 tons/ha of forage containing 7.1% protein and 0.18% P. With intermediate irrigation, it produced 10.9 tons/ha of forage containing 6.6% protein and 0.17% P. Thus, cane bluestem out-produced switchgrass under both dryland and irrigated conditions. Also, cane bluestem yield was maximum on the intermediate water level, while that of switchgrass was maximum on the highest water level. These comparisons indicate that the cane bluestems are as well or better adapted than switchgrass to drought conditions.

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