Increasing utilization efficiency of continuously stocked Old World bluestem pasture


Abstract

The objective of this 2 year study was to identify the optimal height to graze Old World bluestem pasture in the Southern Great Plains under continuous stocking during the growing season. We hypothesized that intensely grazing Old World bluestem pasture would increase utilization efficiency by increasing the proportion of live leaf in the pasture, enhance forage quality and animal performance, and animal performance and root biomass would decline if grazing intensity was beyond an optimal level.

Pastures were maintained at 3 levels of standing crop using continuous variable stocking. Stock adjustments were made weekly. A disc meter was used to maintain pasture disc heights of short (35-40 mm), medium (41-45 mm), and tall (46-55 mm) levels. Average standing crops of short, medium, and tall pastures were 1,500, 1,900, and 2,400 kg ha\(^{-1}\), respectively. On the short pasture treatments the proportion of leaf and live stem was higher (P<0.05) than the proportion of dead stem (P<0.05) and the proportion of dead stem was less (P<0.05) than that on the tall pasture treatments. There were no significant differences (P>0.05) in crude protein of forage between pasture treatments during the vegetative growth phase in spring when forage nitrogen levels were fairly high (> 13%). When the grass began to produce reproductive organs and when forage nitrogen levels were lower (< 1.3%), forage crude protein was greater in the short pastures (P<0.05).

Individual animal performance was greater on the tall than on the short pastures (P<0.10) over all dates. Individual animal performance was greatest when management maximized the proportion of leaf and live stem while minimizing dead stem. Animal performance per hectare was slightly higher on the short and medium height pastures. Both the short and medium height pastures had approximately 70% the root biomass of the tall pastures (P<0.01) at the end of the trial. These results indicate that intense continuous variable stocking of Old World bluestem increases the utilization efficiency, but increases animal production per hectare only marginally, and reduces root biomass to an extent that production may not be sustained from year to year.

Key Words: Bothriochloa ischaemum, continuous variable stocking, forage quality, herbage allowance, “Plains” Old World bluestem, steer performance.

In conjunction with grazed annual cereal grains, Old World bluestem (Bothriochloa ischaemum L.) pastures are used to enhance production and profitability of range-based beef systems in the Southern Plains of North America (Sims and Dewald 1982, Coyne and Bradford 1985, Dewald et al. 1985). Old World bluestem is easy to establish, drought hardy, resistant to defoliation and produces quality forage In spring and summer, but forage quality in late summer through winter is very low (Eck and Sims 1984; Dewald et al. 1985; Dabo et al. 1987). Rapid growth rates in spring are followed by seed production and a decline in green leaf proportion (Sims et al. 1983; Eck and Sims 1984; Dewald et al. 1985; Coyne and Bradford 1986). Consequently, unharvested forage is of inferior nutritive value. Diet quality and intake of animals grazing Old World bluestem is particularly sensitive to the proportion and density of green leaf mass and the leaf to stem ratio (Forbes and Coleman 1986).

Pasture management principles based on understanding the basic biology of grass growth and grazing have been developed in areas of the world that are relatively uniform, cool and moist (Murphy 1990). These principles have not been well tested in the more variable and extreme climate of the Southern Great Plains of North America.

The grazing method of choice in the Southern Great Plains has been continuous stocking. Under continuous stocking, the forage plants are exposed to grazing continuously through the growing season. Since pastures are stocked to the least productive period, stocking rates are conservative. This results in overgrazing of some plants and patches and undergrazing of others. The heavily grazed portions become sparse, unproductive and weedy and the ungrazed portions become rank, self-shade, and are less palatable and nutritious. Unless growing conditions are relatively uniform, these problems are very difficult to control (Blaser et al. 1986; Maxwell and Treacher 1986).

Intense grazing that maintains the pasture in a leafy condition can result in greater production efficiency (Johnson and Parsons 1985; Parsons et al. 1988; Murphy 1990). Photosynthetic rates are greater in younger leaf and the respiratory burden and shading of older plant material is avoided. In addition, production is further enhanced through more rapid nutrient cycling. These factors all result in more growth, an extended growing season and greater levels of water-use-efficiency (McNaughton 1979). Harvest efficiency is increased since a greater percentage of leaf is consumed before it dies and different pasture structure provides the grazing animal greater leaf densities and a diet proportionally greater in leaf and nutrients (Grant et al. 1983; Parsons et al. 1983).
The objective of this study was to identify the optimal height to graze Old World bluestem in the Southern Great Plains to achieve efficient use under continuous stocking. We hypothesize that grazing Old World bluestem pasture intensely will increase the proportion of live leaf and the quality of available forage. High intensity grazing beyond an optimal level is hypothesized to reduce animal productivity, and root biomass compared to pasture grazed less intensively.

Materials and Methods

The study site is located 5 km east of Vernon (34° 10’ N, 100° 16’ W) in north-central Texas. The climate is continental with an average 2,300 frost-free, growing days. Mean annual precipitation is 550 mm, varying from 490 mm to 1,000 mm, that is bimodally distributed with peaks in May (102 mm) and September (81 mm). Annual mean monthly temperature is 17.4°C ranging from 36.4°C in July to –2.3°C in January. Evaporation averages 1,835 mm per annum (607 mm pan). Elevation is 390 m at the research site and slope is 1-3%. Soils are a mix of Bukreek loams (fine-loamy, mixed, thermic Typic Paleustoll), Sagerton clay loams (fine, mixed, thermic Typic Argiustoll), and Wichita clay loams (fine, mixed, thermic Typic Paleustalf). Soils are moderately alkaline (pH = 7.8-8.5), had no measurable nitrogen, moderate levels of phosphorus (12 ppm), high potassium (290 ppm), high calcium (4,540 ppm), high magnesium (600 ppm), no salinity, and very low sodium (<10 ppm) and sulphur (<1 ppm).

The study was conducted on a 4-year-old, weed-free pasture of WW-Spar, Old World Bluestem Bothriochloa ischaemum (L.) Ken var ischaenum (WW-573). Using continuous, variable stocking, pastures were kept at 3 different heights. Stock numbers were adjusted weekly following pasture height measurement using a pasture disc-meter (Bransby et al. 1977). The target disc-meter heights were short (35-40 mm), medium (41-45 mm), and tall (46-55 mm). Each treatment had 2 replicates. Pasture replicate sizes ranged from 3.84 ha to 4.17 ha. In 1992 all pastures were fertilized with 112 kg ha⁻¹ of nitrogen, as urea, in 2 equal dressings prior to expected rainfall in late April and early June. In 1993, only the April fertilizer application (56 kg ha⁻¹) was applied in July 1992 and regressed against height. In 1993, the same procedure was followed using 20 quadrats per treatment. Regressions were developed to describe the relations between standing crop and disc-meter height. The best r² values using this method were 0.92 for 1992 and 1993. Improved r² values were obtained using a multiple regression model which included disc meter height and the percentages of live leaf, dead leaf, and stem. Using this regression, r² values were 0.93, 0.94, and 0.92 for short, medium, and tall pastures, respectively.

Root biomass was estimated at the end of each growing season with soil cores (25 x 900 mm) in the center of 20 randomly located tufts. Coyne and Bradford (1986) found 90% of root biomass in the top 400 mm of soil. Soil was washed from roots on a 0.5 mm sieve (Smucker et al. 1982). Roots were dried at 68°C.

Data Analysis

Standing crop, dry matter production, plant organ proportion, forage quality, animal performance and root biomass data were analyzed using repeated measures analysis of variance to test for differences in treatment means. The main effects were similar using individual dates or equivalent year periods, so year analyses are presented. Above-ground standing crop, dry matter production, and plant organ proportion data were analyzed by date (months) and year using whole-pasture and zone-pasture averages. To analyze pasture zone differences, means per zone were used since terraces made up approximately 10% of the area of each pasture. Multiple regressions were used to predict standing crop from disc meter height and relate forage attributes to animal production. The intercept in these models was not significant so no-intercept models were used. All analyses were carried out using the SAS statistical package (SAS 1985). Least significant difference tests (Steel and Torrie 1960) were used to separate means.

Results and Discussion

Climate

The temperatures in the 1992 growing period were slightly lower than the long-term means but 1993 temperatures were closer to the long-term means but 1993 temperatures were closer...
Fig. 1. Mean monthly weather data at the experimental site for 1992 and 1993 compared to long-term mean monthly (LTMM) data. (A) rainfall, (B) temperature, and (C) evaporation.

Standing Crop, Dry Matter Production and Plant Organ Proportions

Standing crop was significantly different between tall and short treatments (P<0.05), averaging 2,439 and 1,459 kg ha⁻¹, respectively (Table 1). Standing crop was less (P≤0.05) in 1992 than 1993 (1,468 and 2,378 kg ha⁻¹, respectively), but live leaf and live stem standing crop did not differ between years. Differing proportions of dead leaf and dead stem in the standing crop (P≤0.05) occurred between 1992 and 1993. This was due to the presence of dead leaf and stem aftermath in 1993 following mowing compared to burning in 1992.

Forage production through July did not differ between 1992 and 1993 (3,707 kg ha⁻¹ vs 3,167 kg ha⁻¹) (Table 1). However, it did differ between treatments (P≤0.05): (1) 4,520 kg ha⁻¹ for tall, (2) 3,160 kg ha⁻¹ for medium, and (3) 2,631 kg ha⁻¹ for short pastures. However, maximum yield per hectare harvested by grazing does not depend on maximizing the rate of forage production (Grant et al. 1983; Parsons et al. 1983). Harvest efficiency depends primarily on the rate of tissue loss (Parsons et al. 1988). When whole pastures are considered, grazing intensively increased the proportion of live leaf and stem (P≤0.05) and decreased the proportion of dead stem (P≤0.05) in the pasture (Table 1). Whether this translates into increased animal performance depends on the relative rates of intake of nutrients from pastures maintained at different heights (Parsons et al. 1988).

Within each pasture, the cattle grazed the different zones at varying intensities (Table 2). Greater use was made of the terraces. They had lower standing crops but intermediate dry matter production compared to the other zones (Table 2). Standing crops on the terraces (1,623 kg ha⁻¹) were less (P≤0.10) than zones closer and further from water (west: 1,841 kg ha⁻¹ and east: 2,020 kg ha⁻¹, respectively). But the standing crop on the terraces (1623 kg ha⁻¹; Table 2) was more than that of the short treatment pastures (1,459 kg ha⁻¹; Table 1). There was less range in standing crop values between the different zones than between the short, medium, and tall pasture treatments (cf. Tables 1 and 2). This is probably why the proportion of plant parts did not differ between the different zones (Table 2).

Forage Crude Protein

In both years, forage crude protein (CP) declined significantly from relatively high values in May (Table 3). Since these were all hand collected samples, CP was much lower than might be expected from samples gathered by animals from the same pasture. In 1992, the second application of nitrogen fertilizer in late June CP increased through July and August, before declining to low levels in September and October.

The CP values for May 1993 were significantly lower (P≤0.05) than those for May 1992. This is probably due to burning in 1992 compared to mowing in 1993 which resulted in a greater amount of residual dead material in the mowed pastures. Protein concentrations were similar in June of both years (P>0.05).
Table 1. Average plant organ proportions, standing crop and production in Old World bluestem pasture under tall, medium, and short grazing.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant Organ</th>
<th>Standing Crop</th>
<th>Dry matter Production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Live leaf</td>
<td>Dead leaf</td>
<td>Live stem</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Short</td>
<td>38.3ab</td>
<td>22.4</td>
<td>28.0b</td>
</tr>
<tr>
<td>Medium</td>
<td>42.4a</td>
<td>19.2</td>
<td>28.3b</td>
</tr>
<tr>
<td>Tall</td>
<td>35.0b</td>
<td>18.2</td>
<td>33.8a</td>
</tr>
<tr>
<td>1992</td>
<td>47.3A</td>
<td>9.2b</td>
<td>33.8</td>
</tr>
<tr>
<td>1993</td>
<td>29.8b</td>
<td>30.6a</td>
<td>26.3</td>
</tr>
</tbody>
</table>

Means with the same lower case letter are not significant at P<0.05.
Means with the same upper case letter are not significant at P<0.05.

Whenever moisture stress caused plant quiescence, CP dropped significantly. This occurred in July and October 1992, and in July 1993. Coyne and Bradford (1984) observed that extreme summer drought and high temperatures triggered quiescence, which caused a significant decline in forage quality in Old World bluestem (Forbes and Coleman 1986). Dabo et al. (1987) found digestibility of immature stems to be similar to leaves, but stem digestibility declined more rapidly with advancing maturity than that of leaves, and leaf to stem ratios decreased markedly with age.

Table 2. Plant organ proportions, standing crop, and production in different zones within Old World bluestem pasture.

<table>
<thead>
<tr>
<th>Pasture Zone</th>
<th>Plant Organ</th>
<th>Standing Crop</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Live leaf</td>
<td>Dead leaf</td>
<td>Live stem</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>East</td>
<td>44.1</td>
<td>19.3</td>
<td>23.7</td>
</tr>
<tr>
<td>Terrace</td>
<td>45.9</td>
<td>19.2</td>
<td>24.1</td>
</tr>
<tr>
<td>West</td>
<td>46.3</td>
<td>18.4</td>
<td>24.5</td>
</tr>
</tbody>
</table>

Means with the same lower case letter are not significant at P<0.05.

Animal Performance

Individual animal performance was greater on the tall than the short treatment pastures (P<0.10) over all dates. Gain per hectare was greatest in short, intermediate in medium, and least in tall pastures but these differences were not significant (P>0.10)(Table 4). The average daily gains (ADG) of 0.64 to 0.75 kg day⁻¹ compare very favorably with results of Volesky et al. (1994) who recorded ADGs of 0.54 to 0.71 kg day⁻¹ with end of season standing crops of approximately 1,400 kg ha⁻¹. The gain per hectare of 120 to 129 kg ha⁻¹ observed in this study, was much lower than the 260 kg ha⁻¹ recorded by Volesky et al. (1994). Differences in gain per hectare are probably due to the difference in annual precipitation between the 2 locations, viz. 550 mm vs. 800 mm, and lower soil productive potential at our study site.

Regression of ADG against vegetation variables produced 6 significant equations (Table 5). The models indicate that management that maximizes the proportion of leaf and live stem while minimizing dead stem, results in the highest animal performance. This concurs with other work on Old World bluestem which found that digestibility, particularly of stem, declined rapidly with maturity (Forbes and Coleman 1986, Dabo et al. 1987). Under the short grazing treatments of this study, intensive grazing to reduce stem and old tissue also reduced forage on offer.
Average daily gain (kg ha$^{-1}$ day$^{-1}$) on Old World bluestem pasture grazed at short, medium, and tall grazing heights.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Short</th>
<th>Medium</th>
<th>Tall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average daily gain (kg ha$^{-1}$ day$^{-1}$)</td>
<td>0.64$^b$</td>
<td>0.69$^{ab}$</td>
<td>0.75$^a$</td>
</tr>
<tr>
<td>Gain per animal (kg ha$^{-1}$ day$^{-1}$)</td>
<td>49.6$^b$</td>
<td>52.1$^{ab}$</td>
<td>56.1$^a$</td>
</tr>
<tr>
<td>Gain per hectare (kg ha$^{-1}$)</td>
<td>129.1$^b$</td>
<td>122.9$^{ab}$</td>
<td>120.0$^a$</td>
</tr>
</tbody>
</table>

Means with the same upper case letter are not significant at P<0.05. Means with the same lower case letter are not significant at P<0.05.

Conclusions

In both years of this study, forage nitrogen declined significantly from the beginning of May to mid-June (Table 6). Nitrogen fertilizer levels in this study were moderately low (112 kg ha$^{-1}$ of N) and nitrogen was, therefore, probably moderately limiting for the duration. Taliaferro et al. (1975) obtained positive increases in yield following 67<135<269 kg ha$^{-1}$ of N fertilizer. Greater levels of nitrogen would increase photosynthetic efficiency per unit leaf area and maintain a more constant growth rate (Coyne and Bradford 1987). This would also probably improve and hasten energy reserve and root biomass recovery in the latter half of early and late regrowth cycles (Coyne and Bradford 1986) and increase forage quality for most of the growing season.

Table 5. Regressions of average daily gain (ADG) against standing crop and plant proportions on Old World bluestem pasture grazed at different heights (n=48).

<table>
<thead>
<tr>
<th>ADG = (2.05 ± 0.38) - (0.0003 ± 0.0002) standing crop</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>0.0444</td>
</tr>
<tr>
<td>(2)</td>
<td>0.8327</td>
</tr>
<tr>
<td>(3)</td>
<td>0.8214</td>
</tr>
<tr>
<td>(4)</td>
<td>0.7816</td>
</tr>
<tr>
<td>(5)</td>
<td>0.8246</td>
</tr>
<tr>
<td>(6)</td>
<td>0.8146</td>
</tr>
</tbody>
</table>

Continuous variable stocking has been shown to overcome the inefficiencies of set stocking (Johnson and Parsons 1985). When moisture or fertility are not limiting, pastures maintained at a relatively low leaf area index using continuous variable stocking produced less reproductive tissue than pastures kept at greater leaf area index. In these circumstances, greatest animal production was associated with treatments that had lower leaf area index and plant productivity (Grant et al. 1983; Parsons et al. 1983).

In this study, where both moisture and nutrients were limiting, Old World bluestem displayed the same response but of lesser magnitude. Grazing intensively increased the proportion of live and dead leaf in the pasture. Animal performance per hectare was only marginally greater in the medium and short pasture treatments. It is possible that with a greater range in forage allowance a greater difference would have been obtained regarding the proportion of leaf, quality of forage and animal performance per hectare with increasing forage allowance. Continuous variable stocking as practiced in this study would usually be impractical under commercial grazing circumstances. The same effect can be achieved by using temporary fencing to adjust the grazeable area and cutting the balance for hay.

Forage crude protein did not differ between treatments during the vegetative growth phase in spring when forage nitrogen levels were relatively high. When the grass began to produce reproductive organs and when forage nitrogen levels were lower, forage crude protein was greater on the shorter pastures. By splitting fertilizer applications, as in this study, forage growth, forage quality and root and energy reserve replenishment could be significantly enhanced. Such management may allow pastures to be grazed less intensively to achieve efficient and profitable production that
is sustainable from year to year. Volesky (1994) and Volesky et al. (1994) demonstrate that rotational stocking increases utilization and production efficiency and may provide a means of maintaining root biomass, a high proportion of live leaf and utilization efficiency. To improve the utilization and productive efficiency of Old World bluestem pastures, it will be necessary to investigate combining rotational stocking and better soil fertility management while identifying how these plants respond physiologically to such treatments.

I. Literature Cited


Parsons, A.J., I.R. Johnson, and A. Harvey. 1988. Use of a model to optimize the interaction between frequency and severity of intermittent defoliation and to provide a fundamental comparison of the continuous and intermittent defoliation of grass. Grass and Forage Sci. 43:49-59.


