1989

Effects of Manipulation on Foliage Characteristics of *Andropogon gerardii* Vitman

Rosemary A. Ramundo
Division of Biology, 'Kansas State University, Manhattan, Kansas

T. Dawn Shapley
Division of Biology, 'Kansas State University, Manhattan, Kansas

C. L. Turner
Division of Biology, 'Kansas State University, Manhattan, Kansas

M. I. Dyer
Biosphere Research Inc., Route 2, Box 330-A, Lenoir City, Tennessee

T. R. Seastedt
Division of Biology, Kansas State University, Manhattan, Kansas

EFFECTS OF MANIPULATION ON FOLIAGE CHARACTERISTICS OF *ANDROPOGON GERARDII* VITMAN

Rosemary A. Ramundo, T. Dawn Shapley, C. L. Turner
Division of Biology, Kansas State University, Manhattan, Kansas 66506

M. I. Dyer
Biosphere Research Inc., Route 2, Box 330-A, Lenoir City, Tennessee 37771
and
T. R. Seastedt
Division of Biology, Kansas State University, Manhattan, Kansas 66506

Abstract. The effects of burning, mowing, and nitrogen fertilizer on the chlorophyll, nitrogen, and phosphorus content of big bluestem were measured using a factorial experimental design at Konza Prairie Research Natural Area. While spring burning usually increased foliage production, burning had no effect on mid-season chlorophyll or nitrogen concentrations. Chlorophyll concentrations were significantly increased by fertilizer and mowing treatments. Nitrogen concentrations of foliage were higher on fertilized and mowed plots. Mowing also increased phosphorus concentrations of foliage, but nitrogen fertilizer significantly reduced phosphorus concentrations. These results support other research indicating that: 1) nitrogen use efficiency (grams biomass produced per gram of foliage nitrogen) is higher on burned prairie, 2) removal of foliage by mowing results in more nutrient-rich regrowth, and 3) the amount of phosphorus available to big bluestem foliage is limited. The dilution of phosphorus caused by added nitrogen was a consequence of increased productivity on these plots and suggests phosphorus uptake in excess of requirements for maximum growth. The relationships between burning, mowing, and nitrogen on the spectral reflectance patterns of vegetation indicated that chlorophyll (or nitrogen) concentrations of foliage appeared to more strongly affect indices of greenness and plant vigor than did the amount of plant biomass.

Key Words. biomass, burning, mowing, big bluestem, *Andropogon gerardii*, chlorophyll, nitrogen, phosphorus, Kansas

INTRODUCTION

Publications on the factors controlling the productivity of tallgrass prairie are abundant (Knapp and Seastedt 1986, Ojima 1987, Hulbert 1988). Current scientific emphasis is directed at understanding spatial patterns of productivity in relation to topography, fire, and grazing. Interest is increasing in the use of remote sensing procedures in these efforts. Spectral reflectance patterns have been used to monitor seasonal patterns of productivity both within and among terrestrial ecosystems (Goward *et al.* 1985, Asrar *et al.* 1986). For this type of approach to be useful in tallgrass prairie, knowledge of burning, mowing, and grazing on plant spectral reflectance characteristics must be understood on a basis of both per unit of foliage and per unit of vegetation area. Plant physiology and morphology, in conjunction with the absolute amounts of living and dead foliage, will affect the spectral reflectance measurements (Sellers 1985, Waring *et al.* 1985).

This study evaluated the effects of burning, mowing and fertilizer on the chlorophyll, nitrogen, and phosphorus content of the dominant tallgrass species, big bluestem (*Andropogon gerardii* Vitman). These results are then related to the effects of the respective treatments on prairie productivity and the spectral reflectance properties of this vegetation.

STUDY SITE AND METHODS

Research was conducted on the Konza Prairie Research Natural Area in the Flint Hills region of northeastern Kansas. The study area consisted of 32 plots (100 m^2) that had been: 1) annually burned or unburned since 1985, 2) mowed and raked twice per growing season or unmowed since 1985, and 3) fertilized with 10 g/m^2 of nitrogen as ammonium nitrate (NH_4NO_3) or untreated. This experiment consisted of four replicates of eight combinations of burning, mowing, and fertilizer additions. Mowing was conducted in late May and in mid-July. Species composition of these plots is similar to that reported by Hulbert (1988). Big bluestem was the dominant grass, but indiangrass [*Sorghastrum nutans* (L.) Nash] was also abundant. Forbs, including several milkweeds (*Asclepias* spp.) and goldenrods (*Solidago* spp.), were also common, particularly in unmowed plots.

Samples of big bluestem foliage for chlorophyll and nutrient analyses were collected on 3 July 1987 and immediately placed in refrigerated bags and returned to the laboratory. Leaf sheaths were removed prior to measurements. Wet weights of these samples were obtained and samples were then frozen until other analyses were conducted. Quantitative samples for biomass estimates were obtained on 15 July by clipping 0.1 m^2 of vegetation from each plot. Biomass from mowed plots represented regrowth after one mowing while biomass from unmowed plots represented total foliage production.

Methods of both extraction and spectrophotometric analysis of chlorophyll were based on the Delaney technique as used by Knapp and Gilliam (1985). The leaves were taken from the freezer one at a time, thawed by warming gently between the palms, then cut into 1 cm pieces, and weighed on a Mettler balance to 0.01 g. Chlorophyll A, chlorophyll B, and beta carotene were then extracted using 85% acetone, sand, and calcium chloride ($CaCO_3$) with a foil-covered mortar in a pestle. The leaves were ground for 1-2 minutes with a Talboy blender. The ground tissue and acetone were poured into a foil- covered, graduated centrifuge tube, and diluted to 10 ml with acetone. Each sample was centrifuged for 5 minutes and allowed to settle for 1 hour before measured in wavelengths of 750, 663, 644, and 452 nm on a Beckmann DB-GT spectrophotometer (Robbelen 1957).

Nitrogen and phosphorus values for foliage samples were obtained by drying and grinding additional foliage, digesting this tissue with a micro-Kjeldahl method, and determining nitrogen and phosphorus colorimetrically on a Technicon Autoanalyzer.

Spectral reflectance measurements were concurrently obtained by personnel involved on the NASA-FIFE experiment (FIFE = First ISLSCP Field Experiment, ISLSCP = International Satellite Land Surface Climatology Project). The spectral measurements determined total amount of reflected light at specific wavelengths. Here, an index of "greenness" or Green Vegetation Index (GVI) (Kauth and Thomas 1976) based on a linear combination of reflectances of various wavelengths, is used to describe the plots. Another index of plant vigor used to describe the plots, the normalized difference, is a ratio estimator created by subtracting red reflectance from the near-infrared reflectance and dividing this value by the sum of these reflectances (Goward *et al.* 1985).

Statistical analysis of these data employed a three-way ANOVA, using fire, mowing, and nitrogen as main effects. All possible interactions among the treatments were also evaluated. Due to the configuration of the plots, fire effects were tested using a block*fire interaction term. Other effects were evaluated with the error term.

RESULTS

An analysis of variance of nitrogen concentrations indicated no interactions among the main treatments of burning, mowing, and nitrogen additions. Nitrogen concentrations in foliage of big bluestem were higher in the fertilized plots than in control plots (Figure 1). Significantly higher nitrogen concentrations also occurred in mowed than in unmowed plots. Spring burning, however, did not significantly affect nitrogen concentrations (Figure 1).

An analysis of variance also indicated no interactions among the main treatment effects for phosphorus concentrations of foliage. Phosphorus increased in mowed plots at about the same ratio as the increase in nitrogen (Figure 2). In contrast, phosphorus significantly decreased in plots where nitrogen fertilizer was added (Figure 2).

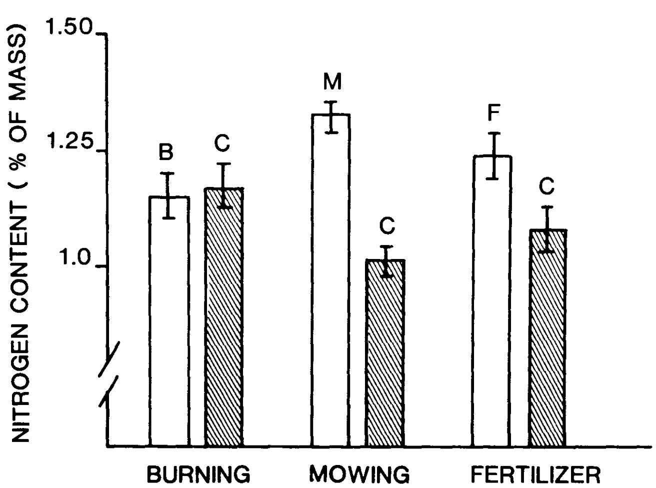

FIG. 1. Nitrogen concentrations of big bluestem foliage. Controls (C), represented by hatched bars, are compared to burned (B) plots, mowed (M) plots, or fertilized (F) plots. Error bars represent one standard error for 16 replicates.

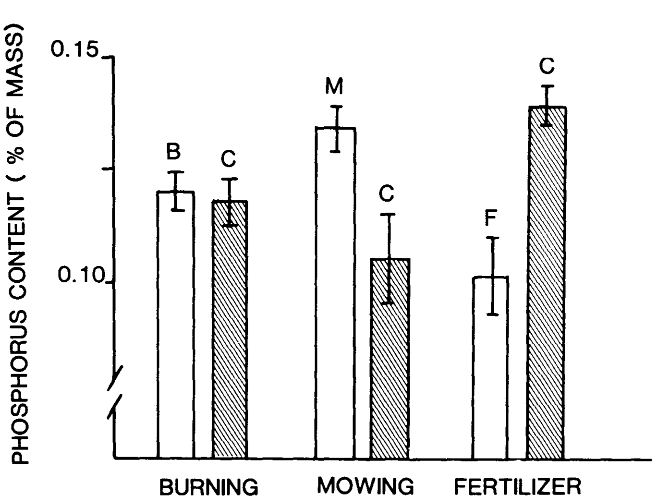

FIG. 2. Phosphorus concentrations of big bluestem foliage. Symbols are same as those used in Figure 1.

Fertilization with ammonium nitrate resulted in higher chlorophyll A and total pigment concentrations in big bluestem foliage (Figures 3 and 4). Mowing also significantly increased pigment concentrations while spring burning had no effect. An analysis of variance indicated modest ($p = 0.05$) interactions between mowing and fertilizer additions (for chlorophyll A concentrations) and for mowing and burning (for total pigment concentrations). Unmowed, unfertilized vegetation had lower chlorophyll A concentrations than mowed, unfertilized vegetation. Concentrations of chlorophyll A were similar for mowed or unmowed but fertilized vegetation. Burning tended to increase pigment concentrations on unmowed sites, but, it decreased concentrations on mowed sites.

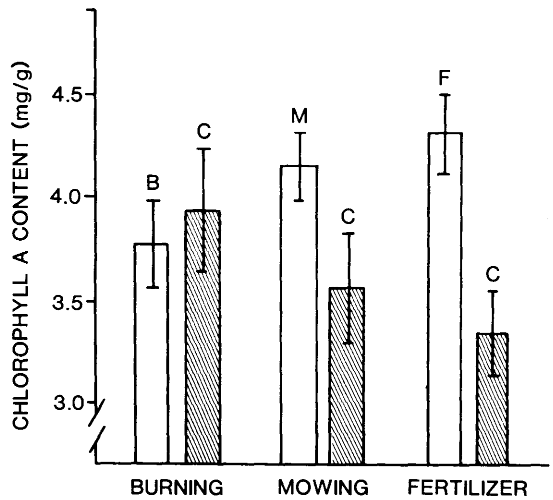

FIG. 3. Chlorophyll A concentrations of big bluestem foliage. Symbols are same as those used in Figure 1.

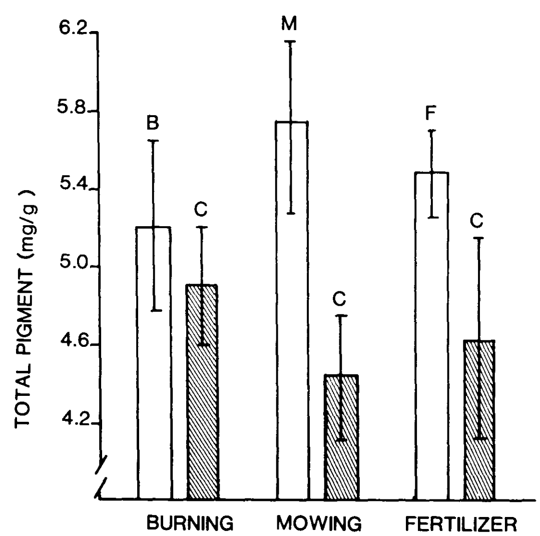

FIG. 4. Total pigment (chlorophyll A, chlorophyll B, and beta carotenes) of big bluestem foliage. Symbols are same as those used in Figure 1.

Plant biomass on the various plots was harvested on 15 July (Figure 5). Regrowth after mowing in late May on mowed plots was much greater on fertilized than on unfertilized plots. Overall, these midseason values show a strong mowing and fertilizer effect, and a non-significant effect of spring burning on plant biomass. Indices of plant greenness and plant vigor associated with this biomass are shown in Figures 6 and 7. When these values are compared with plant biomass (Figure 5), ''greenness'' appears to be more closely associated with nitrogen additions than with biomass. An analysis of variance of the reflectance-derived values indicated that all treatments except mowing and all two-way interactions among treatments were statistically significant. However, the amount of variance attributed to fertilizer was much more significant than any other variable or combination of treatments.

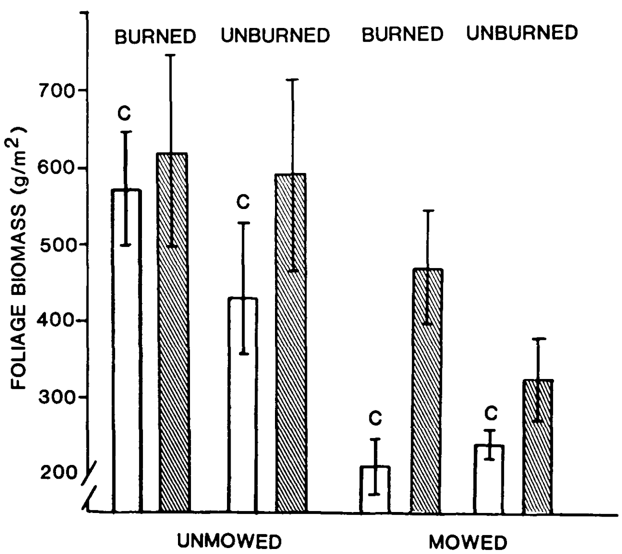

FIG. 5. Midseason foliage biomass on burned, mowed, and fertilized plots. Hatched bars represent the fertilized plots within each mowing and burning treatments.

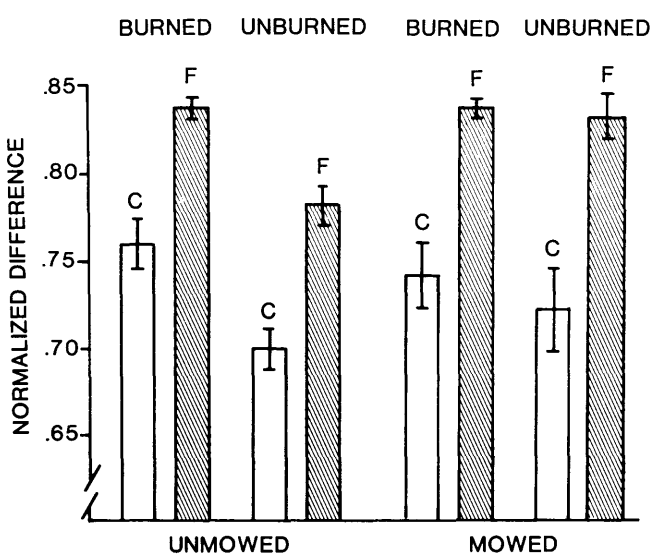

FIG. 6. Normalized difference, another index of plant vigor, for burned, mowed, and fertilized plots. Symbols are the same as those used in Figure 5.

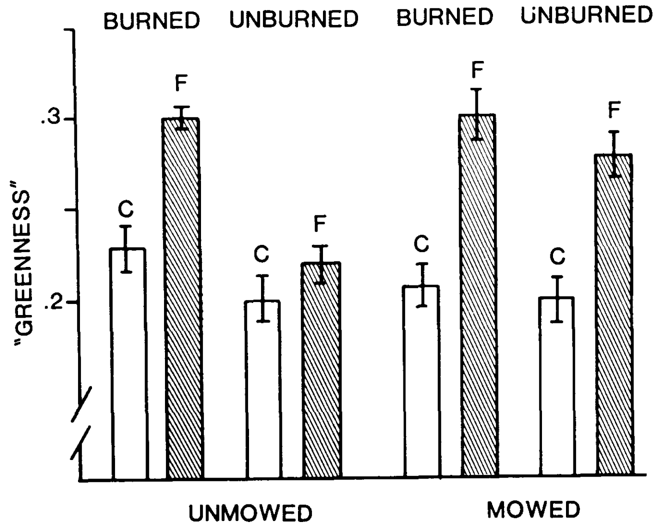

FIG. 7. ''Greenness'' in relation to burning, mowing, and fertilizer treatments. Controls (C), are compared to fertilized plots (F) within each mowing and burning treatment. Bars are one standard error for 8 replicates.

DISCUSSION

Midseason chlorophyll concentrations measured here for big bluestem are, on average, somewhat higher than values reported by other investigators (Bray 1960, Ovington and Lawrence 1967, Old 1969, Knapp and Gilliam 1985). These higher values reported in this study may reflect differences in methodologies rather than actual species differences or differences attributed to site effects. The age of the foliage at the time the chlorophyll measurements were made is important, although Ovington and Lawrence (1967) found little seasonal dynamics in concentrations of total chlorophyll in a Minnesota prairie.

Spring burning did not affect midseason chlorophyll or nitrogen concentrations. While the seasonality of nitrogen content of burned and unburned vegetation may differ markedly (Owensby *et al.* 1970), the overall amount of nitrogen available to vegetation on burned sites is not markedly different from unburned sites, and may in fact be less on burned sites (Ojima 1987). This implies that the increased productivity observed on burned sites in most years corresponds to increased nitrogen use efficiency by this vegetation.

Old (1969) measured the effects of nitrogen addition on midseason chlorophyll content and reported about a 20% increase in chlorophyll, a relative difference similar to that found in this study (Figure 3). This increase appears to be linearly related to the nitrogen content of this tissue. In contrast, phosphorus concentrations were not related to chlorophyll concentrations. While mowing increased chlorophyll, nitrogen, and phosphorus concentrations, addition of ammonium nitrate increased chlorophyll and nitrogen concentrations, but decreased phosphorus content. These data therefore suggest that big bluestem will accumulate phosphorus in concentrations higher than those limiting growth. Therefore, these plants exhibit luxury uptake of this element relative to nitrogen and/or other elements.

These results indicate that ''greenness'' as measured with the normalized difference procedure was sensitive to both burning and chlorophyll (nitrogen) content of the vegetation. The former treatment, which in this study did not significantly affect nitrogen concentrations, removed standing dead plant materials and litter and, thereby, changed the reflectance properties of the soil surface. Fertilization and mowing strongly affected nitrogen and chlorophyll concentrations. The reduction in biomass resulting from mowing may negate the positive effect that mowing had on chlorophyll and nitrogen content, such that measurements of greenness after a certain period of regrowth on mowed plots did not show a strong mowing effect. Other studies have suggested that canopy reflectance was sensitive to the physiological status of the plant at the time of measurement (Sellers 1985). This work tends to support this concept in that plots with reduced biomass but enhanced nitrogen content tended to have equal or greater indices of greenness than unmowed but unfertilized vegetation (Figure 7). These findings have important implications to studies on assessment of plant productivity or vegetation interactions with the atmosphere by remote sensing methods. Models using only foliage biomass or leaf area are unlikely to provide accurate estimates of either subsequent productivity or water-gas interactions.

ACKNOWLEDGEMENTS

This research was supported by NASA (NAG-5-897) and NSF (BSR-8514327) grants to Kansas State University. T. Dawn Shapley's current address is University of Kansas Medical Center, Kansas City, Kansas 66103.

LITERATURE CITED

Asrar, G., E.T. Kanemasu, G.P. Miller, and R.L. Weiser. 1986. Light B, Binterception and leaf area estimates from measurements of grass canopy reflectance. IEEE Transactions Geoscience and Remote Sensing 24:76-82.

Bray, J.R. 1960. The chlorophyll content of some native and managed plant communities in central Minnesota. American Journal Botany 38:313-333.

Goward, S.N., C.J. Tucker, and D.G. Dye. 1985. North American vegetation patterns observed with meteorological satellite data. Vegetatio 64:3-14.

Hulbert, L.C. 1988. Causes of fire effects in tallgrass prairie. Ecology 69:46-58.

Kauth, R.J., and C.S. Thomas. 1976. The tassel cap - a graphic description of the spectral-temporal development of agricultural crops as seen by Landsat. Proceedings of the Symposium on Machine Processing of Remotely Sensed Data. Purdue University, West Lafayette, Indiana.

Knapp, A.K., and F.S. Gilliam. 1985. Response of *Andropogon gerardii* (Poaceae) to fire-induced high *vs.* low irradiance environments in tallgrass prairie: leaf structure and photosynthetic pigments. American Journal of Botany 72:1668-1671.

Knapp, A.K., and T.R. Seastedt. 1986. Detritus accumulation limits productivity of tallgrass prairie. BioScience 36:662-668.

Ojima, D.S. 1987. The short-term and long-term effects of burning on tallgrass ecosystem properties and dynamics. Doctor of Philosophy Dissertation, Colorado State University, Fort Collins.

Old, S.M. 1969. Plant production in an Illinois prairie. Ecological Monographs 39:353-383.

Owensby, C.E., R.M. Hyde, and K.L. Anderson. 1970. Effects of clipping and supplemental nitrogen and water on loamy upland bluestem range. Journal of Range Management 23:341-346.

Ovington, J.D., and D.B. Lawrence. 1967. Comparative chlorophyll and energy studies of prairie, savanna, oakwood, and maize field ecosystems. Ecology 48:515-522.

Robbelen, G. 1957. Untersuchungen an strahleninduzierten blattarbumutanten von *Arabidopsis thaliana* (L.) Verebungslehre 88:189-193.

Sellers, P.J. 1985. Canopy reflectance, photosynthesis and transpiration. International Journal of Remote Sensing 6:1335-1372.

Waring, R.H., J.D. Aber, J.M. Melillo, and B. Moore III. 1985. Precursors of change in terrestrial ecosystems. BioScience 36:433-438.