Home | 2005 Annual Report

Plant Responses to Different Grazing Intensities in the Missouri Coteau of North Dakota

Results and Discussion

Specific leaf area

The interactions of grazing intensity and species were significant ($p<0.05$) for three parameters: specific leaf area (SLA), photosynthetic rate and frequency of occurrence (Table 1). Smooth brome had significantly higher SLA than the other four species at each grazing intensity (Table 1, Table 2, Figure 1). The other four species did not have a response to grazing intensity and had no significant difference between species under the same grazing conditions (Table 2 and Figure 1).

Table 1. Results of analysis of variance with grazing intensity (df=2), species (df=4) and intensity × species interaction (df=8) as factors.

	Intensity P	**Species P**	**Intensity × Species P**
SLA	0.0029**	<0.0001***	0.0002***
Leaf nitrogen content	<0.0001***	<0.0001***	0.0911
Photosynthesis rate	<0.0001***	<0.0001***	0.0027**
Vcmax	0.0277*	<0.0001***	0.2961
Jmax	0.0617	<0.0001***	0.2758
Frequency response	0.0735	<0.0001***	<0.0001***

Notes: Vcmax is maximum rate of carboxylation limited by the amount, activity, and kinetics of Rubisco.
Jmax is the maximum rate of carboxylation limited by electron transport.
*P<0.05; **P<0.01; ***P<0.001.

Figure 1. Specific leaf area for five species from different grazing intensities. Means followed by the same letter are not significantly different.

Photosynthetic rate

Of the five selected species, stiff sunflower possessed the most significant advantage. Its photosynthetic rate increased significantly under moderate grazing intensity and then decreased significantly with heavy grazing. Western wheatgrass had a significantly higher photosynthetic rate with heavy grazing intensity (Table 2 and Figure 2). The other three species were not affected significantly by grazing intensity and did not differ from each other in photosynthetic rate.

Figure 2. Photosynthetic rate for five species from different grazing intensities. Means followed by the same letter are not significantly different.

Frequency response

The joint effect of the species-grazing intensity interaction had a significant effect on frequency response (Table 1). The intensity factor had a marginally significant effect on frequency response. Smooth brome and stiff sunflower reached the highest frequency in the ungrazed treatment and the frequency response was reduced with increased grazing intensity. Smooth brome was most abundant under ungrazed conditions compared to the other species. Stiff goldenrod had an unusual response to grazing; it appeared to be favored by moderate grazing intensity and had reduced abundance at the heavy and un-grazed intensities. Western wheatgrass and green needlegrass were significantly less frequent compared to smooth brome, stiff sunflower, and stiff goldenrod and did not differ between grazing levels (Table 2 and Figure 3).

Previous research (see Long-Term Ecological Grazing Intensity Research in the Missouri Coteau on North Dakota) has shown that after 18 years of cattle grazing, smooth brome and stiff sunflower appeared to be favored by no grazing, stiff goldenrod is favored by moderate grazing, and western wheatgrass and green needlegrass are favored by heavy grazing. Our results were consistent with these findings.

Leaf nitrogen content

Though the intensity-species interaction for the leaf nitrogen content was marginally significant, the leaf nitrogen content differed significantly between species (Table 1). Of the five species, smooth brome had the highest level of leaf nitrogen (2.7% of dry mass) and green needlegrass had the lowest level (1.7% of dry mass) (Table 2). The grazing intensity was very significant (Table 1). Nitrogen content was significantly lower on the ungrazed treatment, but this may be because more of this material is old growth.

Vcmax and Jmax

Vcmax was significantly affected by the species and the grazing intensity. The grazing intensity had marginal effects on Jmax, although it differed significantly between species (Table 1). This means that 18 years of grazing had effects on the physiological level. Stiff sunflower had significantly higher values of both Vcmax and Jmax than did the other species (Table 2). Stiff sunflower's rate of Vcmax was 152.2 $\mu molCO_2 m^{-2} s^{-1}$, and the second highest Vcmax was stiff goldenrod, 119.2 $\mu molCO_2 m^{-2} s^{-1}$, which was significantly higher than western wheatgrass, smooth brome and green needlegrass. These three species had no significant differences in Vcmax values. Of the three grazing intensities, the moderate grazing intensity had a mean Vcmax of 116.2 $\mu molCO_2 m^{-2} s^{-1}$, significantly higher than the un-grazed. Stiff sunflower had the highest Jmax value, 265.0 $\mu molCO_2 m^{-2} s^{-1}$, significantly greater than the other four species, which were not significantly different. Based on the photosynthesis analysis, Vcmax, ranged from 62.5 $\mu molm^{-2} s^{-1}$ for green needlegrass to 170.5 $\mu molm^{-2} s^{-1}$ for stiff sunflower, and averaged 108.8 $\mu molm^{-2} s^{-1}$ for all species. The range of Jmax was from 138.5 $\mu molm^{-2}s^{-1}$ for stiff goldenrod to 294.8 $\mu molm^{-2}s^{-1}$ for stiff sunflower, with a mean of 196.4 $\mu molm^{-2} s^{-1}$ for all species (Table 2). According to Wullschleger (1993), Jmax ranged from 17 $\mu molm^{-2}s^{-1}$ to 372 $\mu molm^{-2}s^{-1}$ for 109 C_3 species. Therefore, these results are within an acceptable range.

Table 2. Measured values of plant parameters, including SLA, leaf nitrogen content, photosynthetic rate, Jmax, Vcmax and frequency response at ungrazed, moderately grazed, and heavily grazed intensities.

	Western wheatgrass	Smooth brome	Stiff sunflower	Stiff goldenrod	Green needlegrass
SLA (cm^{-2} g^{-1})					
Ungrazed	100.8(3.2)c[1]	162.9(39.0)b	99.6(1.8)c	111.3(6.7)c	84.2 (36.4)c

Moderately grazed	105.6(7.5)c	236.0(16.8)a	101.1(3.9)c	102.7(8.8)c	102.8(8.8)c	
Heavily grazed	107.2(28.1)c	260.6(11.8)a	94.9(13.0)c	98.7(3.4)c	115.1(5.0)c	
Leaf nitrogen content (% dry mass)						**Mean**
Ungrazed	2.0(0.0)	2.2(0.3)	1.9(0.3)	2.1(0.0)	1.5(0.0)	1.9b
Moderately grazed	2.2(0.1)	2.9(0.2)	2.2(0.2)	2.5(0.2)	1.7(0.1)	2.3a
Heavily grazed	2.2(0.1)	2.9(0.2)	1.9(0.1)	2.5(0.1)	1.9(0.1)	2.3a
Mean	2.1c	2.7a	2.0c	2.4b	1.7d	
Photosynthetic rate ($\mu molCO_2 m^{-2} s^{-1}$)						
Ungrazed	11.5(3.5)e	13.3(1.9)de	23.9(0.6)bc	15.4(3.2)cde	10.93(1.2)e	
Moderately grazed	13.5(5.8)de	12.6(1.8)de	36.8(3.4)a	21.1(3.6)bcd	16.2(3.8)cde	
Heavily grazed	21.8(0.6)bcd	16.3(2.0)cde	25.7(4.2)b	21.1(6.0)bcd	18.5(2.8)bcde	
Vcmax ($\mu molCO_2 m^{-2} s^{-1}$)						**Mean**
Ungrazed	77.0(25.1)	80.4(11.9)	155.1(19.1)	105.8(2.8)	62.5(6.3)	95.5b
Moderately grazed	100.9(16.3)	84.3(13.4)	170.5(24.5)	125.4(20.4)	100.1(9.0)	116.2a
Heavily grazed	117.4(0.0)	82.3(11.7)	132.5(28.9)	121.7(27.9)	85.1(13.0)	106.3ba
Mean	93.0c	82.3c	152.7a	119.2b	82.6c	
Jmax ($\mu molCO_2 m^{-2} s^{-1}$)						
Ungrazed	160.2(59.3)	178.5(14.0)	267.9(7.3)	138.5(0.0)	153.5(4.0)	
Moderately grazed	215.7(27.3)	165.0(18.7)	294.8(38.0)	214.4(39.1)	190.8(42.1)	
Heavily grazed	220.8(29.2)	161.2(37.9)	232.2(46.7)	186.0(41.6	166.9(22.7)	
Mean	198.9b	168.2b	265.0a	191.4b	170.4b	
Frequency of occurrence (%)						
Ungrazed	12.3(6.4)ef	65.3(22.2) a	51.9(7.9) bc	41.5(10.9) cd	6.9(4.8) f	
Moderately grazed	17.0(5.7)ef	39.8(6.3) d	42.5(8.1)cd	54.7(17.9) b	6.8(4.2) f	
Heavily grazed	21.4(9.7)f	46.2(15.0)bcd	38.1(11.1)d	44.8(24.2) bcd	7.5(3.4) f	

Note: Values in parentheses are standard deviation.
SLA: specific leaf area (leaf area divided by the dry mass)
Vcmax: the maximum rate of Rubisco-mediated carboxylation.
Jmax: the maximum rate of carboxylation limited by electron transport.
[1] Means followed by the same letter are not significantly different within each parameter.

Figure 3. Frequency of occurrence for five species for different grazing intensities. Means followed by the same letter are not significantly different.

Discussion

Plants of different life-forms (grasses versus forbs) typically differ in their tolerance to foliage loss. The interaction of the functional groups and intensities was significant ($P<0.05$) and although the photosynthetic rate of the forbs and grasses were significantly altered by the grazing intensities, forbs had a higher photosynthetic rate than did grasses, regardless of treatment (Table 3). In this situation, it seems that the inherent characteristics of functional groups were altered by environmental stress. For the grasses (western wheatgrass, smooth brome and green needlegrass), average photosynthesis was significantly different between no grazing and heavy grazing, 11.9 $\mu molm^{-2}s^{-1}$ and 18.9 $\mu molm^{-2}s^{-1}$ ($p<0.05$), respectively. The means of forbs rate of photosynthesis showed no significant difference between these two grazing intensities. Within the grasses, western wheatgrass had a significantly lower photosynthetic rate for the ungrazed treatment compared to the heavy grazed treatment. However, smooth brome and green needlegrass showed no response (Table 2). Within the forbs, photosynthesis of stiff sunflower showed a response to

grazing. Under the moderate intensity, forbs had a much higher photosynthetic rate, 28.9 $\mu molm^{-2}s^{-1}$, than in the other two treatments (Table 3).

Table 3. The photosynthetic rate of forbs and grasses under different grazing intensity conditions ($\mu mol\ CO_2\ m^{-2}\ s^{-1}$).

Functional Groups	No Grazing	Moderate Grazing	Heavy Grazing
Forbs	19.7bc[1]	28.9a	23.4b
Grasses	11.9d	14.1cd	18.9bc

[1] Means followed by the same letter are not significantly different at $P<0.05$

Our results were in accordance with the hypothesis that grasses are less photosynthetically productive than forbs (Bazzaz, 1979; Chabot and Hicks, 1982). There were few differences in SLA and leaf nitrogen content between plants in grazed and ungrazed sites for both grasses and forbs. Increases in plant photosynthetic rate following grazing have been reported for many grass species in different studies (Painter and Detling, 1981; Caldwell et al., 1981; Detling and Painter, 1983).

In summary, some plant species had a significantly altered photosynthetic rate, leaf nitrogen content, SLA, Vcmax, Jmax, and photosynthesis- internal CO_2 response curves between the grazed treatments and un-grazed treatment. This suggests that the plants may have adapted to long-term grazing by changing physiological and morphological traits.

This research was conducted just one time in one year and measured only select values, so the results will need more research. This was a basic research study and its results are intended to benefit plant selection and breeding. We will conduct further research and explore more practical information for management actions and decisions on land use.

Previous section -- Materials and Methods
Table of Contents