HERBAGE NITROGEN CONTENTS AFTER A PRAIRIE PRESCRIBED BURN IN THE BLACK HILLS

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ABSTRACT

Effects fall burning of prairie have on the next year's herbage nitrogen content were studied. Warm-season little bluestem *(Schizachyrium scoparium [Michx] Nash.)* and prairie dropseed *(Sporobolus heterolepsis)* and cool-season *Carex spp.* and *Poa spp.* were the most abundant grass-type plants. The mineral soil did not heat to 38°C during the burn. The nitrogen content of the 0-2-cm layer did not decrease but plant-available phosphorus and organic matter increased due to the addition of charred plant fragments. Post-burn yields of warm-season herbage decreased significantly ($p>0.05$) in burned areas, and cool-season herbage yields increased in three of the four areas. Mulch weight was significantly reduced ($p>0.05$). Unburned plot herbage N (8.8 g kg^{-1}) was significantly larger ($p>0.05$) than the herbage of burned plots (7.6 g kg^{-1}). The N content of cool-season herbage (9.2 g kg^{-1}) was significantly larger ($p>0.05$) than the N content of the warm-season herbage (7.2 g kg^{-1}). Burned and unburned plots, respectively, had 5890 and 8304 g N ha-1 if the amounts in the two types of herbage were added. Nitrogen in the standing herbage and mulch of the unburned areas likely leached to the soil and supplied N to the next season's herbage.

Keywords

Grass-fires, prairie preservation, pine encroachment

INTRODUCTION

The new growth of grass, following a prescribed burn is frequently darker green and more vigorous than in unburned areas. This study was initiated to determine if the herbage N content is increased following a fire. Prairie fires can immediately increase the amount of NH_4-N, plant-available P, and organic matter in the 0-2-cm soil layer (White and Gartner, 1975). Soil NH_4-N and plant-available-P amounts increased as temperatures of a 10-minute heat treatment increased from ambient to 400°C. A similar study with soils from Ponderosa pine *(Pinus ponderosa)* forest found total N decreased in samples heated above 200°C (White et al., 1973). Soil organic matter, total N, NH_4-N, and extractable PO_4-P contents were similar after fall or spring burns of meadow and coniferous understories and for unburned areas in the Black Hills (White and Gartner, 1994a). However, soil lost organic matter, total N, and total PO_4-P beneath burned slash piles and the C/N of the 0-2-cm layer decreased. The NH_4-N increased in the 0-5-cm soil layer and NO_3–N decreased in the 2-5-cm layer (White and Gartner,1994b). Changes 15 or 16 months after the slash was burned were compatible with the initial changes. Fyles et al. (1991) reported slash burning two years earlier had not reduced N levels below those needed for early plantation growth except where slash was completely burned on coarse-textured soils. Ryan and Covington (1986) found the 0-15-cm soil layer NH_4-N and NH_4-N plus NO_3-N increased in prescribed burns of saw timber but not in stands of pole or sapling classes. Kovacic et al. (1986) also found NH_4-N and NH_4- plus NO_3-N increased but total N did not change in a 30-day post-burn period. Covington et al. (1991) reported NH_4-N increased immediately but that NO_3-N increased the following year. Monleon et al. (1997) found soil total C and inorganic N amounts had increased four months after prescribed underburning in Ponderosa pine in Oregon. Inorganic N amounts decreased to the amounts in the control plots within a year. Five years after prescribed burning, total C and N concentrations and N-mineralization rates were smaller.

MATERIALS AND METHODS

Prescribed-burn treatment

Thirty six and a half hectares of a prairie in the forested Black Hills were burned by the Forest Service in October, 1973 (Gartner and White, 1974) to control encroaching Ponderosa pine (380 trees ha^{-1}, 97% were 2.5 to 5 cm dia.). Oven-dry pre-burn herbaceous fuels in Area 1 through 4 located, respectively, on N-NW-, N-NE-, W-, and S-facing slopes were 2900, 5300, 3400, and 4100 kg ha_{-1}. Moisture contents were 16 percent for soils and 15 percent for fuels. As measured by materials with specific melting points, temperatures in the mulch layer, about 2.5 cm above the mineral soil, approached 540°C but did not reach 38°C in the mineral soil. In small saplings, temperatures above the soil ranged from 150 to 480°C at 30 cm, 65 to 150°C at 60 cm, and less than 65°C at 90 cm. Wind speeds were about 40-km hr^{-1} so the fire moved rapidly across the area and did not consume the mulch layer where it was moist.

Sampling

Prior to the prescribed burn, four pairs of 50x50 cm plots were located on 1. a N-NW-sloping colluvial area, 2. a N-NE-facing upland area, 3. a west-sloping narrow ridge with shallow soils, and 4. a steep south-facing slope. A 15x15-m area on each landscape was not burned. The 50x50-cm plots were located at two corners of the unburned areas in each of the four landscapes. Each 50x50-cm area was divided into four 25x25-cm subplots — two were untreated and two had the vegetation burned in the summer. The following

April, the 0-2-cm soil surface layer was sampled for laboratory analysis by methods described by Jackson (1958) for Walkley-Black organic matter, total macro-kjeldahl N, and 0.1N-NaCl-extracted P subsequently determined by the ascorbic acid procedure (Watanabe and Olsen, 1965). Soil particle sizes were determined (Soil Conservation Service, 1972) on a samples from each of the eight 50x50-cm plot.

The *plant species-sampling unit* consisted of locating four shoots lying on a transect and measuring the distances between them to calculate the shoot density. The transects were perpendicular to the even-numbered foot intervals in a hundred-foot measuring tape and the transects were one hundred foot long.

The samples for *herbage and mulch weights* were collected from five 20x50-cm areas located randomly on either side of nine transects located at the 5,10, 15,…45 foot-locations. Thus the weights are averages of 45 (9x5) sampling units. The herbage was dried, divided into warm-season and cool-season grass-type plants, ground, and analyzed for kjeldahl N content.

Cool- and warm-season vegetation that grew was sampled September 20 the season after the fall prescribed burn. Vegetation was collected from each 15x15-m unburned area and the adjacent burned area. Soil samples were collected from each of the four pairs of 50x50-cm areas located on the different landscapes. Vegetation was sampled along line transects. Herbage was divided into cool- and warm-season grass-like species dried, ground, and total macrokjeldahl N was determined.

Pre-burn vegetation

The most abundant pre-burn species are listed in Table 1 for the plots in the four landscapes studied. Warm-season little bluestem and prairie sand dropseed had the most shoots and the cool-season *Carex* and *Poa* plants had the third and fourth most abundant shoots. The abundance of the individual species were variable in the burned and unburned areas. The sums of the warm- or cool-season species are less variable except for landscape Area 2 where warm-season shoots in the areas to be burned are about half those in the plots not to be burned.

RESULTS AND DISCUSSION

Soils

Differences between the burned and the unburned plot soil content of organic matter and available PO_4-P were significant but not for the content of total N (Table 2). The total N content was correlated with the organic matter content for both the burned (r^2=0.80) and unburned (r^2=0.90) plot soils. The regression coefficients for the two were not significantly different (p=0.05). If the organic matter content is converted to carbon by the 58% conversion factor (Jackson, 1958), the soil C/N ratios are 16.9 and 16.2 for the burned- and un-

Table 1. Average number of shoots per square meter at four study areas for grasses, sedges, forbs, and woody plants in areas to be burned (B) or unburned (U).

		AREAS							
		1		2		3		4	
Plant	**Season#**	**B**	**U**	**B**	**U**	**B**	**U**	**B**	**U**
Scsc*	W	238	498	400	920	840	640	493	435
Sphe	W	310	82	251	250	155	128	493	97
Carex	C	233	379	122	143	273	241	311	210
Poa	C	200	74	8	72	19	23	83	127
Kocr	C	92	59	55	84	19	-	30	7
Stco	C	21	-	2	12	-	-	18	45
Agsu	C	7	15	2	12	-	-	3	-
Bogr	W	15	-	9	-	14	-	56	-
Ange	W	12	-	-	-	47	7	104	134
Spcr	W	2	-	-	-	-	-	-	-
Stvi	C	2	-	-	-	-	-	-	-
Sihy	W	-	-	2	-	9	-	18	23
Bocu	W	-	-	-	-	75	98	96	97
Bohr	W	-	-	-	-	47	45	8	75
Sum of W's	577	580	662	1170	1188	918	843	861	
Sum of C's	550	527	259	323	311	264	445	389	
Sum of forbs	217	336	94	132	169	151	179	67	
Sum of shrubs	42	97	74	310	119	15	38	-	
Sum of pines	17	15	118	213	33	7	13	-	

#W-warm season species. C-cool season species
*Abbreviations derived from first two letters of the genus and the species in order listed: *Schizachyrium scoparium, Sporobolus heterolepis, Carex species, Poa species, Koeleria cristata, Stipa comata, Agropyron subsecundem, Bouteloua gracilis, Andropogon gerardi, Sporobolus crytandrus, Stipa veridula, Sitanion hystrix, Bouteloa curtipendula, Bouteloua hirsuta*

Table 2. Mean total N, organic matter, and available PO_4-P contents of the surface 2 cm of soil in plots where vegetation was burned (B) or unburned (U).

Slope aspect	**Sub-plots**	**Total N**		**Organic matter**		**Avail. PO_4-P**	
		B	**U**	**B**	**U**	**B**	**U**
		$g\ kg^{-1}$		$g\ kg^{-1}$		$g\ kg^{-1}$	
N-NW	W	6.3	5.9	199	179	2.2	2.4
	E	7.1	6.7	188	177	1.6	1.6
South	E	3.9	3.6	102	90	1.5	1.7
	W	4.2	3.4	113	91	2.4	1.6
N-NE	S	7.2	7.2	241	213	3.9	3.1
	N	4.9	4.7	170	125	2.6	1.1
West	S	4.2	4.5	99	116	2.1	1.9
	N	4.1	4.2	113	127	2.0	1.4
	Mean	5.2	5.0	153	140	2.3	1.8
ANOV Significance							
Subplots		p>0.01		p>0.01		p>0.10	
Burn treatment		NS		p>0.01		p>0.05	
Interactions		NS		NS		NS	

burned-plot soils,respectively. The total soil-N contents were not significantly different for the burned and unburned plots but the means for the burned plots was slightly greater. Nitrogen-organic matter regression coefficients for burned and unburned plot soils were not significantly different. Burning the vegetation did not change the composition of the vegetation but did increase the amount of N and C in the soil. Available P contents were significantly greater for the burned-plot soils than for the unburned ones. Regressions of available P with organic matter for soils from burned and unburned plots explained 32% and 45% of the variation, respectively, in the data and the two regression were not significantly different (p=0.05). Thus, total N and organic matter contents of the 0-2-cm soil layer in the burned treatment plots probably are increased by the addition of small, unburned plant fragments. The available P contents may be increased either by the addition of the fragments or because the fire warmed the soil sufficiently to make P more available.

The percent clay in the soil samples collected at the diagonally located corners of the unburned areas were for the four landscape positions in numerical order 20.5 vs 21.2; 21.8 vs 19.9; 22.3 vs 18.4; and 20.0 vs 22.0. Thus the soil textures were quite uniform across the area and should not be a factor in explaining the differences in soil organic matter, total N, or available P.

Post-burn vegetation

Prescribed burning decreased the growth of warm-season grasses and increased the growth of cool-season species in Areas 1 through 3 but not in Area 4 (Table 3) where fire consumed the dry mulch. Area 4 was on a steep slope with weakly developed soil where little bluestem growth is favored over the growth of cool-season grasses (White, 1971, 1991). Mean yields of warm-season species were significantly greater (p>0.05) for unburned than burned plots (Table 3). Soils in Areas 1, 2, and 3 are more suited for cool- species than in Area 4 and prescribed burning increased their yield but not significantly. Mulch was significantly reduced (p>0.05) by the prescribed burn but the fire did not significantly increase the populations of forbs and shrubs.

Nitrogen content of the herbage.

Herbage for the N analysis was collected from 15x15-m unburned areas and from the adjacent burned areas. The soil samples from the 25x25-cm burned and unburned plots were collected at the two diagonally located corners of the unburned areas. Thus the soil samples were representative of both the burned and unburned plots. Differences in the N content can be attributed to the burn treatment and not to soil differences.

Cool-season herbage had a larger N content than the warm-season herbage (Table 4). The preceding fall-burn treatment decreased the N content of both the warm- and cool-season herbage. However, the soil N contents were not significantly different (Table 2) so the plant and soil N contents are not directly related. The herbage N contents are related directly to the treatments. Burned- and unburned-plot grass herbage (warm plus cool season)

Table 3. Weight of oven-dry live vegetation, and percent composition in burned (B) and unburned (U) areas at the end of the growing season following the fall prescribed burn.

	AREA							
	1		2		3		4	
	B	U	B	U	B	U	B	U
Warm-season grasses and sedge								
Weight kg ha^{-1}	643	887	715	821	556	690	540	734
Composition %	55	70	51	67	47	64	50	49
Cool-season grasses								
Weight kg ha^{-1}	111	57	213	193	174	98	323	532
Composition %	10	5	15	16	15	9	30	36
Forbs								
Weight kg ha^{-1}	209	175	176	93	157	159	191	220
Composition %	18	14	13	8	13	15	18	15
Shrubs								
Weight kg ha^{-1}	200	154	297	126	290	133	32	8
Composition %	17	12	21	10	27	12	3	1
Mulch								
Weight kg ha^{-1}	59	1400	540	1822	4	692	0	1569
Total live vegetation								
Weight kg $ha\text{-}^{1}$	1162	1273	1402	1233	1177	1080	1086	1494

Table 4. Mean total N contents of warm- and cool-season grassy plants where vegetation was burned (B) and unburned (U).

	VEGETATION TYPE				
	Warm season		Cool season		
Area	B	U	B	U	Mean
			g N kg^{-1}		
1	7.6	8.6	7.9	9.9	8.3
2	6.6	7.1	9.7	9.4	8.2
3	6.2	7.6	8.5	10.0	8.1
4	6.0	8.1	8.8	9.8	8.2
Mean	6.6	7.9	8.7	9.8	

Warm and cool season means, 7.2 and 9.2, and B and U means, 7.6 and 8.8, were both significantly different ($p>0.05$). Areas were not significantly different, $p=0.05$.

contained, respectively, 5,890 and 8,304 g N ha^{-1}, and they are significantly different. The unburned plot herbage may contain the N leached during the winter from the standing dead vegetation and mulch (White, 1973a and b).

CONCLUSIONS

The vigorous appearance of vegetation after a prairie fire is likely caused by the reduction in the total weight of herbage, which increases the amount of N, P, and other elements available to this remaining vegetation. Burning did not increase the soil N content but did increase the soil organic matter and available PO_4-P, likely because charred plant fragments were added to the soil. The grass herbage N content, the season after the prescribe burn, was larger in the unburned plots than in the burned ones. Burning volatilized the nitrogen in the herbage so that it was not cycled to the next seasons growth.

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