Rangeland Ecol Manage 65:101–104 | January 2012 | DOI: 10.2111/REM-D-10-00142.1

Research Note

Mineral Nitrogen in a Crested Wheatgrass Stand: Implications for Suppression of Cheatgrass

Robert R. Blank[1] *and Tye Morgan*[2]

Authors are [1]*Soil Scientist and* [2]*Research Technician, US Department of Agriculture–Agricultural Research Service, Great Basin Rangelands Research Unit, Reno, NV 89512, USA.*

Abstract

Cheatgrass (*Bromus tectorum* L.) is an exotic annual grass causing ecosystem degradation in western US rangelands. We investigated potential mechanisms by which crested wheatgrass (*Agropyron cristatum* L. Gaertn., *Agropyron desertorum* [Fisch. {Ex Link} Scult.]) suppresses the growth and invasibility of cheatgrass. Research focused on monthly mineral soil N availability and the proportional concentration of NH_4^+-N in a crested wheatgrass community by microsite (crested wheatgrass, unvegetated interspace, shrub subcanopy) and soil depth (0–15, 15–30 cm) over a 1-yr period. Mineral soil N in crested wheatgrass microsites ranged from 0.24 to 1.66 $\text{mmol} \cdot \text{kg}^{-1}$ and was not appreciably lower than the other microsites or other ecosystems we have measured in the Great Basin. The molar proportion of NH_4^+-N in the mineral N pool of crested wheatgrass averaged over 85% for the year and is significantly higher than the other microsites and far greater than other plant communities we have measured in the Great Basin. We conclude that crested wheatgrass does not suppress cheatgrass by controlling mineral N below a threshold level; rather, we hypothesize that it may limit nitrification and thereby reduce NO_3^--N availability to the nitrophile cheatgrass.

Resumen

El pasto cheatgrass (*Bromus tectorum* L.) es un pasto exótico anual que está causando degradación en el ecosistema en los pastizales del oeste de los Estados Unidos. Investigamos los mecanismos potenciales por los cuales los pasto (*Agropyron cristatum* L. Gaertn. y *Agropyron desertorum* [Fisch. {Ex Link} Scult.]) suprimen el crecimiento y la habilidad de invasión del pasto cheatgrass. La investigación se enfocó en la disponibilidad mensual de nitrógeno mineral en el suelo (N), y la concentración proporcional de NH_4^+-N en una comunidad de *A. cristatum* L. Gaertn. por micro-sitios (*A. cristatum* L. Gaertn., inter-espacios sin vegetación y sub-dosel) con una profundidad del suelo de (0–15, 15–30 cm) por un periodo de un año. El nitrógeno mineral del suelo en *A. cristatum* L. Gaertn. varían de 0.24 a 1.66 $\text{mmol} \cdot \text{kg}^{-1}$ y no se aprecio más profundo que en los otros micro-sitios u otros ecosistemas que fueron medidos en la Great Basin. La proporción molar de NH_4^+-N en el concentrado de minerales de N de *A. cristatum* L. Gaertn. promedio arriba del 85% en el año y es significativamente mayor que los otros micro-sitios y bastante más grande que las otras comunidades de plantas que medimos en la Great Basin. Concluimos que el *A. cristatum* L. Gaertn. no suprime el pasto cheatgrass a través de controlar el nitrógeno abajo del nivel de tolerancia; en vez de eso, planteamos la hipótesis de que puede limitarse la nitrificación y por eso reducir la disponibilidad de NO_3^--N para la nitro filiación del pasto cheatgrass.

Key Words: control, growth, nitrification, soil nitrogen

INTRODUCTION

In western US rangelands, over 300 introduced weeds have impacted native ecosystems (DiTomaso 2000). A portion of introduced weeds can become highly invasive and through ‘‘ecosystem engineering’’ can effect changes in soil physical and chemical properties (Chapin et al. 1997; Crooks 2002; Wright and Jones 2004). An invaded soil system may have altered nutrient cycling, nutrient availability, and microbial communities creating a positive feedback favoring the invasive species (Ehrenfeld 2003; Callaway et al. 2004).

Cheatgrass (*Bromus tectorum* L.) is the introduced weed with perhaps the largest ecological impact in western rangelands (Knapp 1996). Its invasive success has been influenced by myriad factors including landscape disturbance, wide phenotypic plasticity, rapid growth rate, prolific seed production, and positive growth response to elevated atmospheric CO_2 (Klemmedson and Smith 1964; Ziska et al. 2005; Chambers et al. 2007). Moreover, cheatgrass is nitrophilic—its growth and competitive ability is stimulated by elevated soil N availability (Kay and Evans 1965; Wilson et al. 1966; Vasquez et al. 2008a). Strategies to lower soil N availability can increase the competitive potential of slower growing native grasses, forbs, and shrubs (Lowe et al. 2003).

A successful rehabilitation strategy for weed-infested rangelands, at least in the short-term, has been to reduce available soil N by microbial immobilization of N via application of a labile C source (Reever Morghan and Seastedt 1999; Blumenthal et al. 2003). Alternatively, one can potentially reduce available soil N by planting species that control soil N levels to lower values (James et al. 2008). Crested wheatgrass (*Agropyron desertorum*, *Agropyron cristatum*) is an exotic perennial grass planted extensively in the west for forage, improving degraded range-

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Correspondence: Robert R. Blank, US Dept of Agriculture–Agricultural Research Service, 920 Valley Rd, Reno, NV 89512, USA. Email: bob.blank@ars.usda.gov

Manuscript received 30 August 2010; manuscript accepted 28 June 2011.

lands, and erosion control (Rogler and Lorenz 1983; Young and Evans 1986). Established crested wheatgrass can suppress cheatgrass (Huber and Goodrich 1999), but no research has been undertaken to elucidate mechanisms. Our purpose is to report on the seasonal patterns of soil mineral N pools (NO_3^--N + NH_4^+-N) in a crested wheatgrass stand in northern Nevada, seeded in 1985. This stand has few cheatgrass plants, suggesting some form of suppression. Our initial working hypothesis posited that established crested wheatgrass reduces mineral soil N availability to a level below which cheatgrass is less competitive.

METHODS

We worked in a crested wheatgrass stand about 20 km north northwest of Reno, Nevada (lat 39°40′51″N; long 119°55′36″W) at an elevation of 1 592 m. Average annual precipitation is 28 cm. The soil is Aquinas sandy loam, a fine-loamy, mixed, superactive, mesic Haploxeralfic Argidurid, and developed in mixed granitic and volcanic colluvium. In 1985 following a wildfire, the area was seeded to cultivar Hycrest crested wheatgrass, a hybrid between *A. cristatum* and *A. desertorum*. In March 2009, a 100 × 140 m site was established in a uniform area with similar slope and aspect. Site vegetation is dominated by Hycrest crested wheatgrass, with lesser amounts of the shrubs Morman tea (*Ephedra nevadensis* S. Wats.), desert peach (*Prunus andersonii* Gray), and big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* Beetle and Young), the forbs hawksbeard (*Crepis acuminata* Nutt.), fiddleneck (*Amsinckia tessellata* A. Gray), and the grasses bluegrass (*Poa secunda* [J. Presl]), and squirreltail (*Elymus elymoides* [Raf. Swezey]). Cheatgrass is a minor component, but can assume dominance in areas in which crested wheatgrass did not establish or have died over time. A grid pattern was established and each month six different randomly selected grid intersections were chosen for sampling. At each of the six intersections, three microsites were sampled: center of the nearest crested wheatgrass, center of the nearest unvegetated interspace, and mid-subcanopy of the nearest shrub. Depths sampled were 0–15 cm (surface litter removed) and 15–30 cm. Soil was sieved to remove > 2-mm particles, homogenized and stored in plastic bags. A subsample was dried to 105°C for moisture content and to correct data to an oven dry basis. On fresh samples, we quantified 1.5 M KCl-extractable N, which is a measure of mineral N readily available to plant roots (Bundy and Meisinger 1994). Extractions were done the same day as collection. Data were analyzed using a mixed-model analysis of variance, with repeated measures over soil depth. Fixed variables were time (12 mo) and depth (0–15, 15–30 cm) with microsite (crested wheatgrass, interspace, shrub subcanopy) as the random variable. Total mineral N was log transformed to normalize.

RESULTS

Mineral soil N availability was influenced by significant ($P \leq 0.05$) microsite × depth and depth × time interactions (Fig. 1). Overall, crested wheatgrass ($0.39\ mmol \cdot kg^{-1}$; SE = 0.04) and shrub ($0.43\ mmol \cdot kg^{-1}$; SE = 0.05) microsites had statistically greater mineral N than interspaces ($0.29\ mmol \cdot kg^{-1}$; SE = 0.03). Overall, mineral N was greater in the 0–15 cm depth ($0.53\ mmol \cdot kg^{-1}$; SE = 0.04) than the 15–30 cm depth ($0.21\ mmol \cdot kg^{-1}$; SE = 0.01), and its interaction with microsite occurred in the 0–15 cm depth where crested wheatgrass ($0.59\ mmol \cdot kg^{-1}$; SE = 0.07) and shrub microsites ($0.61\ mmol \cdot kg^{-1}$; SE = 0.09) were significantly greater than interspace microsites ($0.38\ mmol \cdot kg^{-1}$; SE = 0.05). Mineral N was greatest during the winter months but largely controlled by the 0–15 cm depth increment. The depth × time interaction was due to significantly greater mineral N in the 0–15 cm depth increment on January 2010, February 2010, and March 2010.

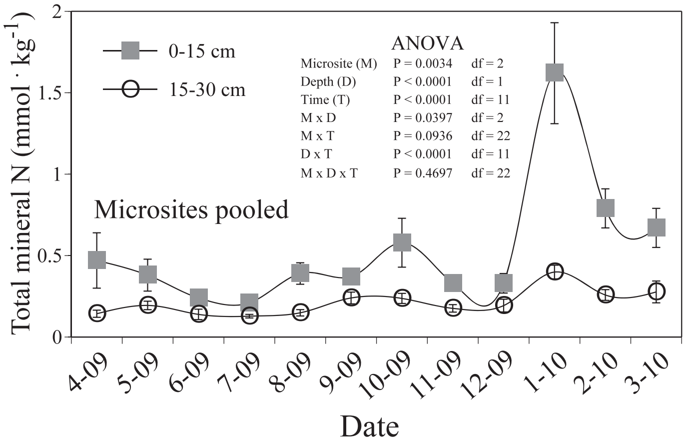

Figure 1. Graph showing significant microsite × time and depth × time interactions for mineral soil N. Bars are standard errors. Data fitted to spline interpolation.

The molar proportion of NH_4^+-N in the mineral N pool was affected by a significant ($P \leq 0.05$) microsite × depth × time interaction (Fig. 2). Overall, crested wheatgrass microsites had a significantly greater proportion of NH_4^+-N (85% SE = 1.2) than the shrub (72% SE = 2) and interspace (75% SE = 1) microsites with dates of August 2009, September 2009, and November 2009 largely controlling the overall differences. All microsites had the greatest proportion of mineral N in the NH_4^+-N form in May 2009 (rapid plant growth) and during the winter. The three-way interaction occurred during August 2009 and September 2009, whence there were significant differences between shrub and interspace microsites for the 15–30 cm depth increment, but not the 0–15 cm increment.

DISCUSSION

Our working hypothesis asks if crested wheatgrass controls mineral soil N (NH_4^+-N and NO_3^--N) availability to levels below which cheatgrass is not as competitive. Low availability of soil N may allow native mid- and late-seral species to be successful against invasive annuals such as cheatgrass (Vasquez et al. 2008b). Unfortunately, we are unaware of any known threshold values of soil mineral N availability whence cheatgrass becomes less competitive. Insight into potential effects of measured mineral N levels in the crested wheatgrass stand can be accomplished by comparing among microsites. The average mineral soil N in the crested wheatgrass microsites, 0–15 cm depth, was $0.53\ mmol \cdot kg^{-1}$ and not significantly different than the shrub microsites (0.61 mmol · kg^{-1}) but significantly greater than interspace microsites (0.38 mmol · kg^{-1}). Chen and Stark (2000) reported that soil beneath crested wheatgrass (15-yr-old stand) had greater NO_3^--N than soil from interspaces or from sagebrush canopies. Furthermore, mineral N values measured in other communities, including sites occupied by cheatgrass (Table 1), are much lower than values measured beneath crested wheatgrass in this study. Microsite differences in mineral N availability are not unexpected because individual plant species regulate and constrain biochemical cycling (Cornwell et al. 2008). The yearly range of mineral soil N in the crested wheatgrass microsite, 0–15 cm, varied from 0.24 mmol · kg^{-1} in April 2009 to 1.66 mmol · kg^{-1} in January 2010, which suggests some risk to invasion (Davis et al. 2000). Given these data, there is no compelling evidence that crested wheatgrass, at least at the particular site we chose, reduces mineral N availability below some threshold level and we, therefore, must reject our working hypothesis.

Our data suggests another possible mechanism, not originally hypothesized, by which established crested wheatgrass may suppress cheatgrass. Given the arid environment, we were quite surprised that for all dates, the molar proportion of NH_4^+-N in the mineral N pool beneath crested wheatgrass exceeded 65% and for 6 mo exceeded 90% and was statistically greater than the shrub and interspace microsites (Fig. 2). Moreover, the molar proportion of NH_4^+-N beneath crested wheatgrass greatly exceeds values obtained in other ecosystems in northern Nevada (Table 1). These data suggest that crested wheatgrass interacts with the soil to somehow reduce the rate of nitrification. Maintaining more mineral N in the NH_4^+-N form may decrease its availability to cheatgrass. Cheatgrass can utilize both NH_4^+-N and NO_3^--N, but has more rapid uptake kinetics for NO_3^--N (MacKown et al. 2009). Moreover, in these arid environments with high temporal variability in soil water content, having a larger proportion of mineral N in the highly mobile NO_3^--N form would increase the likelihood of transport to roots (Barber 1995). It also has been shown that cheatgrass can elevate soil nitrification rates (Norton et al. 2008). We propose that a potentially fruitful research area in the invasion ecology of cheatgrass is to test a hypothesis that plant communities, which poise the proportion of NH_4^+-N in the mineral pool at high levels, may be resistant to cheatgrass

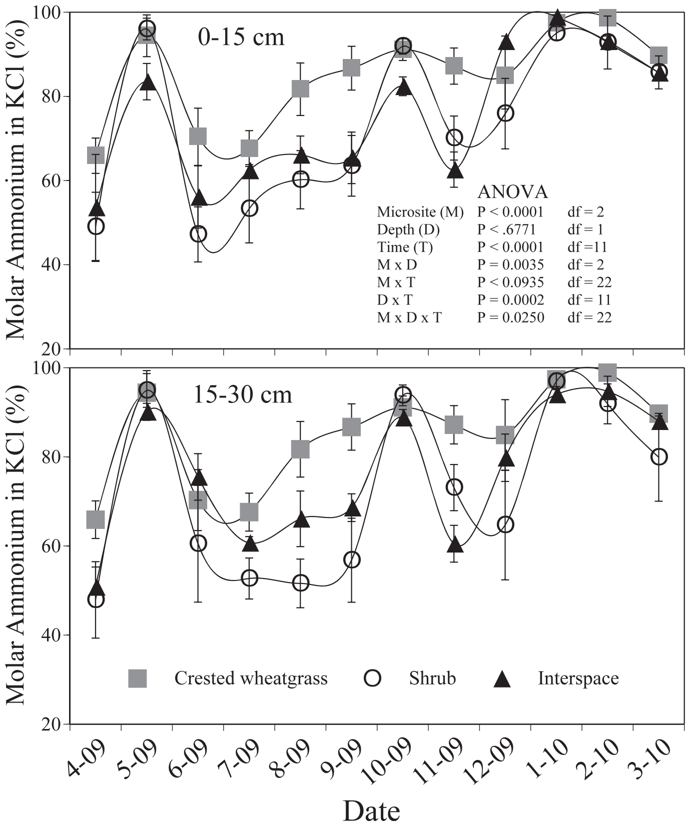

Figure 2. Graphs showing significant microsite × time interaction for molar % of NH_4^+-N in mineral soil N. Bars are standard errors. Data fitted to spline interpolation.

Table 1. Mineral soil N and molar proportion of NH_4^+-N in the mineral pool for several plant communities in Nevada.

Location	Date	Community[1]	Microsite	No. samples	Parent material	Depth	Mineral N	Mole NH_4^+-N
						cm	mmol · kg^{-1}	%
Lat 41°13′40″N, long 117°24′14″W	December 2001	Intact sagebrush	Shrub interspace	4	Loess	0–5	0.63 (0.11)	11.1 (3.3)
	December 2001	Intact sagebrush	Shrub interspace	4	Loess	5–15	0.16 (0.03)	13.0 (3.2)
	December 2001	Intact sagebrush	Sagebrush subcanopy	4	Loess	0–5	0.76 (0.29)	14.9 (1.8)
	December 2001	Intact sagebrush	Sagebrush subcanopy	4	Loess	5–15	0.12 (0.01)	12.3 (4.1)
	December 2001	Burned sagebrush	Cheatgrass	4	Loess	0–5	0.52 (0.14)	10.9 (4.9)
	December 2001	Burned sagebrush	Cheatgrass	4	Loess	5–15	0.25 (0.08)	14.1 (2.3)
Lat 39°09′33″N, long 117°23′33″W	May 2002	Pinyon-Juniper	Interspace	4	Welded Tuff	0–3	1.67 (0.23)	51.3 (6.2)
	May 2002	Pinyon-Juniper	Interspace	4	Welded Tuff	3–8	0.92 (0.11)	41.6 (7.4)
	May 2002	Pinyon-Juniper	Sagebrush subcanopy	4	Welded Tuff	0–3	1.82 (0.26)	28.1 (2.7)
	May 2002	Pinyon-Juniper	Sagebrush subcanopy	4	Welded Tuff	3–8	0.82 (0.04)	30.3 (4.1)
	May 2002	Pinyon-Juniper	Juniper understory	4	Welded Tuff	0–3	1.02 (0.34)	43.8 (2.8)
	May 2002	Pinyon-Juniper	Juniper understory	4	Welded Tuff	3–8	0.41 (0.08)	44.2 (0.8)
Lat 40°08′14″N, long 120°04′38″W	April 1998–May 2010	Invaded winterfat	Cheatgrass	241	Eolian sand over lacustrine	0–20	0.21 (0.02)	32.3 (1.9)
	April 1998–May 2010	Invaded winterfat	Winterfat	83		0–20	0.15 (0.02)	23.6 (2.8)

[1] Data from studies undertaken by Agricultural Research Service, Reno, soils lab using similar analytical proctocols to the present study. Standard errors are in parentheses.

invasion. In California, exotic grasses greatly increased nitrification rates (Hawkes et al. 2005).

MANAGEMENT IMPLICATIONS

Understanding mechanisms by which perennial grasses suppress invasive annual grasses would aide in revegetation efforts. Crested wheatgrass does not appear to suppress cheatgrass by reducing mineral soil N below a threshold level. Rather, our data suggest that crested wheatgrass may inhibit cheatgrass expansion by limiting the rate of soil nitrification, thus causing the mineral N fraction to have a high proportion of NH_4^+-N. We propose, as a hypothesis for testing, that native perennial communities also reduce nitrification. Nitrapyrin, a synthetic nitrification inhibitor, has been shown to decrease plant density and herbage of the annual grass medusahead and the density and cover of cheatgrass relative to controls (Young et al. 1997, 1998). The use of chemical nitrification inhibitors to control cheatgrass should be researched.

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