Bromus tectorum (Cheatgrass): Monitoring an Invasion for 10 Years

R.R. Blank and T. Morgan
USDA-ARS, Exotic and Invasive Weed Research Unit
Reno, NV; bob.blank@ars.usda.gov

In a *Krascheninnikovia lanata* (winterfat) community in the Honey Lake Valley of northeastern, CA we have monitored the effect of *B. tectorum* (an Eurasian exotic annual grass) invasion on surface soil properties. In 1999 a transect of 13 plots, 50 m apart was established, at which time only plots 1-5 were invaded. In 2009 all plots had been invaded. Within 5 m of each plot center, 0-30 cm soil samples from interspace locations were collected multiple times per year and analyzed for availability of N, P, Ca, Mg, K, Fe and Mn and enzyme activities. Pooled over all sampling dates and relative to non-invaded plots, *B. tectorum* invasion fostered significant increases in available N (0.22 vs. 0.16 mmol kg^{-1}), net N mineralization potential (0.25 vs. 0.18 mmol kg^{-1}), Solution P (6.9 vs. 5.1 µmol L^{-1}), phosphatase activity (0.46 vs. 0.33 µmol g^{-1} hr^{-1}), and amidase activity (8.5 vs. 5.8 µmol g^{-1} hr^{-1}). For the plots initially invaded in 1999, unexpected trends over 10 years included decline in phosphatase activity (2000=0.51; 2010=0.10 µmol g^{-1} hr^{-1}) and solution phase Ca^{+2} (2000=4.3; 2010=0.4 mmol L^{-1}). We hypothesize that solution phase Ca^{+2} decreased because increased bioturbation, upon *B. tectorum* invasion, brought solid phase $CaCO_3$ to the soil surface and controlled Ca^{+2} solubility to a lower level.

THE STUDY AREA

The study area is in the Honey Lake Valley of northeastern CA (40°08'N 120°04'W). The soil developed in lake sediments and coarse offshore bar sands reworked by wind. The soil is a Xeric Haplocalcid and the described pedon was invaded by *B. tectorum* for about 10 years. Yearly precipitation averages 230 mm, the average maximum temperature is 18°C, and average minimum temperature is 1°C.

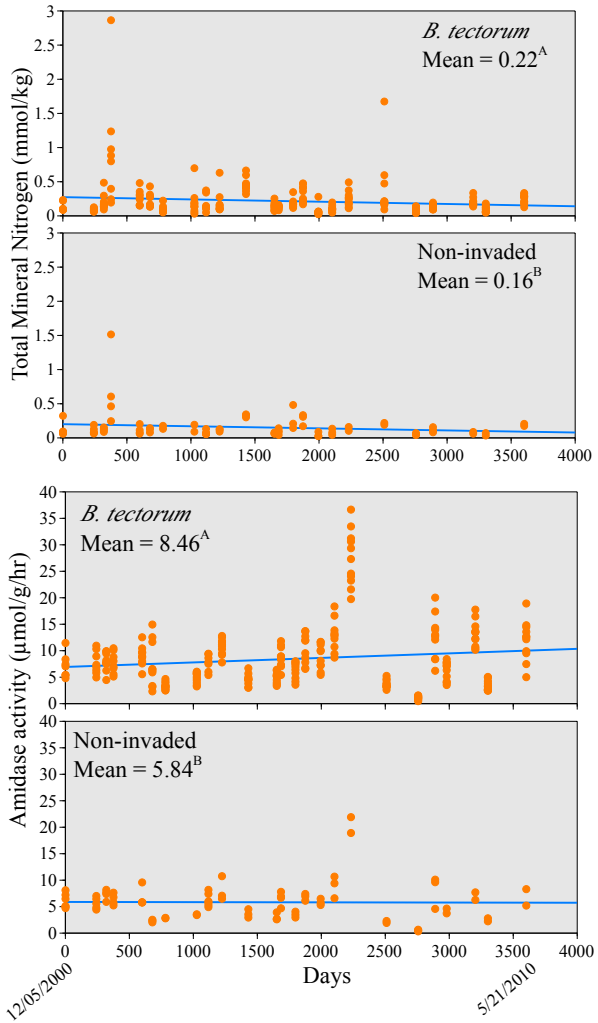
Photo taken in 2007 looking southwest and encompassing first area invaded by *B. tectorum*.

Horizon	Depth	Texture	Munsell	% CCE	% C	% N
A	0-15	Loamy sand	10YR6/3	0	.60	.056
AC	15-25	Sandy loam	10YR6/3	.30	.65	.045
C1	25-35	Fine sandy loam	10YR7/3	1.20	.36	.056
C2	35-80	Loam	10YR7/4	1.21	.56	.056
C3	80-120+	Silt loam	10YR7/2	1.18	.38	.043

EXPERIMENTAL

In about 1997, a *Krascheninnikovia lanata* (winterfat) community became invaded by *Bromus tectorum* (cheatgrass). In 1999, we set up a 13 point transect 50 m apart from the initial invaded front northeast to the yet un-invaded community. Periodically each year, soil samples were collected near each transect point from shrub interspace microsites, 0-30 cm depth, and analyzed for various soil attributes.

TOTAL MINERAL N AND AMIDASE ACTIVITY

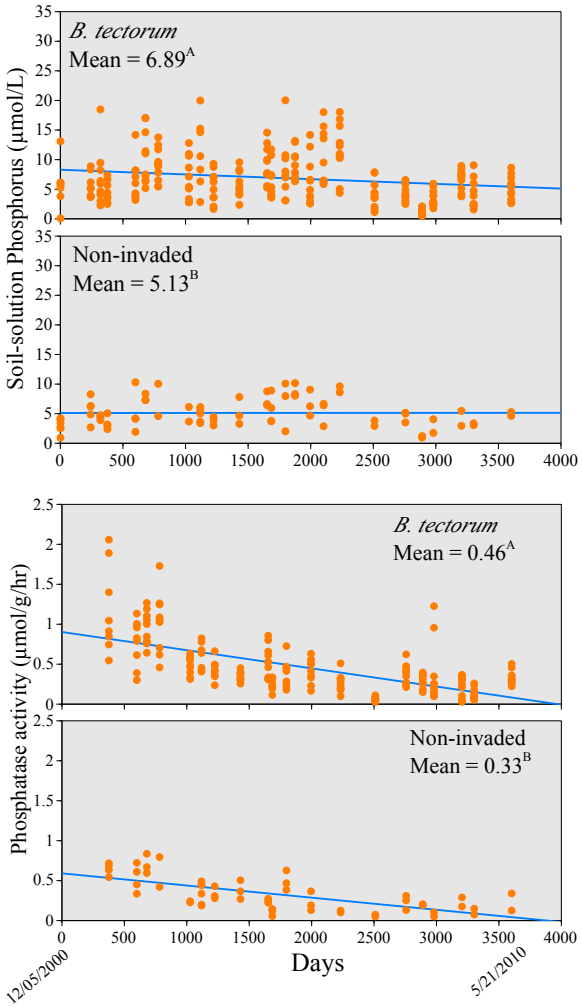


RESULTS: Mineral N was significantly greater on *B. tectorum* invaded sites than non-invaded sites. Trend line shows slight decline in mineral N over 10 years. The N-cleaving enzyme had significantly greater activity on *B. tectorum* invaded plots, and trends upward as time of invasion increases.

INTERPRETATION: *B. tectorum* increases mineral N relative to non-invaded sites. Given the huge uptake in soil N from invaded sites relative to largely un-vegetated interspaces in non-invaded areas, greater mineral N in the soil is surprising. Greater amidase activity in invaded soils may partially explain elevated N availability.

Photos of the study area. Left photo shows the yet non-invaded zone occupied by *K. lanata* with largely un-vegetated interspaces. Right photo shows area that has been invaded for three years. Notice that the shrub interspaces are completely occupied by *B. tectorum*.

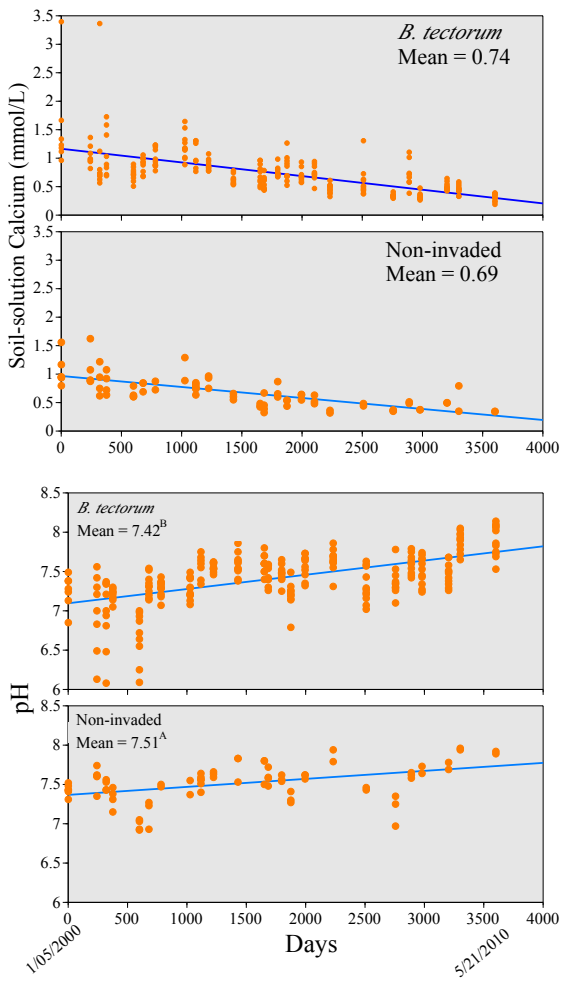
SOIL-SOLUTION ORTHO-P AND PHOSPHATASE ACTIVITY



RESULTS: Overall, soil-solution phosphorus levels were significantly greater on *B. tectorum* invaded sites. No trend in solution phosphorus with time is evident for non-invaded soils. For invaded soils, however, the overall trend is downward, but data breaks into two patterns. From 2000 to 2006, levels of phosphorus trended upward then declined sharply and remained constant for the next four years. Phosphatase activity was significantly greater for invaded soils, and for both invaded and non-invaded soils trended downward with time.

INTERPRETATION: Remarkably, solution phosphorus levels were greater in invaded soils, even though the far greater *B. tectorum* biomass would uptake more phosphorus. We have shown in greenhouse studies that *B. tectorum* increases solution phosphorus levels, relative to unplanted controls, possibly via the exudation of organic acids. Higher phosphatase levels in invaded soils suggest *B. tectorum* may be accessing, to a greater extent, organic pools of phosphorus. The rapid decline in solution phosphorus levels with time could be a function of simple plant depletion of the pool, but could also be due to chemisorption of phosphorus on $CaCO_3$, which increased due to bioturbation (see Ca panel). The decline in phosphatase activity in both invaded and non-invaded soils is perplexing and may also be a function of bioturbation as even non-invaded soils were bioturbated as the cheatgrass expansion grew closer.

SOIL-SOLUTION Ca^{+2} AND pH



RESULTS: A surprising finding of this study was the steady decline of solution phase Ca^{+2} and corresponding steady increase in soil pH in both invaded and non-invaded plots.

INTERPRETATION: When the initial transect was established in 1999, surface soils were tested for their reaction to 1N HCl (test for carbonates). At that time none of the 13 plots effervesced. As time increased, we noticed that a greater proportion of plots did effervesce and by 2008 all plots consistently effervesced. In 1999, field notes and photographs of all the plots revealed that evidence of bioturbation was absent. Looking over plot photos taken each year, it was apparent that mounds of soil, indicative of burrowing activity, were becoming more plentiful. Indeed, by 2010 it is difficult to find undisturbed areas (see bottom photo). We conclude that invasion by *B. tectorum* fostered greater burrowing animal activity which mixed lower carbonate-rich soil with the surface soil and thereby increased soil pH and controlled solution Ca^{+2} activity to a lower level. An increase in carbonate in surface soil may also explain declining levels of solution phosphorus due to surface complexation.

Photo taken in June 2010 showing extensive bioturbation by an unidentified burrowing rodent. The lighter colored un-vegetated material strongly effervesces in HCl and likely affects surface soil nutrient availability relative to a non-bioturbated surface soil.

GENERAL DISCUSSION

We have monitored for 10 years the effect of *Bromus tectorum* (cheatgrass) invasion on surface soil properties. The literature is replete with evidence of "ecosystem engineering" or "positive feedback" by invasive plant species, which can increase their competitive stature. Our data adds to the list that invasion by *B. tectorum* changes soil properties in a relatively short time period. Invasion by *B. tectorum* has affected biogeochemical cycling of carbon, nitrogen, phosphorus, and calcium (and possibly other elements) either directly or by fostering increased bioturbation. What are the long-term consequences to invasion of this ecosystem by *B. tectorum*? Firstly, by direct competition, the invasive grass is decreasing the population and health of the important wildlife forage *K. lanata* (winterfat). Secondly, the density of *B. tectorum* places the site at risk of wildfire and complete loss of *K. lanata*, volatilization of nitrogen and carbon, and potential loss of the highly wind-erodible surface soil. Thirdly, bioturbation is increasing the level of $CaCO_3$ in the surface soil which will affect nutrient availability, particularly phosphorus. We hypothesize that occupation by *B. tectorum* over the long-term will produce a uniquely different soil with different successional potential and perhaps even negative feedback to *B. tectorum*.

K. lanata, flowering in late spring, is a highly nutritious shrub and important winter forage for wildlife. In plots invaded for 10 years by *B. tectorum*, about a third of *K. lanata* plants have died.

Support dog, Herman, enjoying a day off.