Predictors of nitrogen-fixing activity across a local gradient in fire history for a temperate semiarid grassland

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Introduction

Available nitrogen is a main resource limiting plant production. In temperate grasslands, free-living N_2 fixation has been estimated to range from 0.1–21 kg N × ha^{-1} × yr^{-1} (Reed et al. 2011) and has the potential to affect plant productivity. The regulators of free-living N_2 fixer activity are thought to be ecosystem specific (Fig. 1). Little is known about fire effects and regulators in temperate semiarid grasslands.

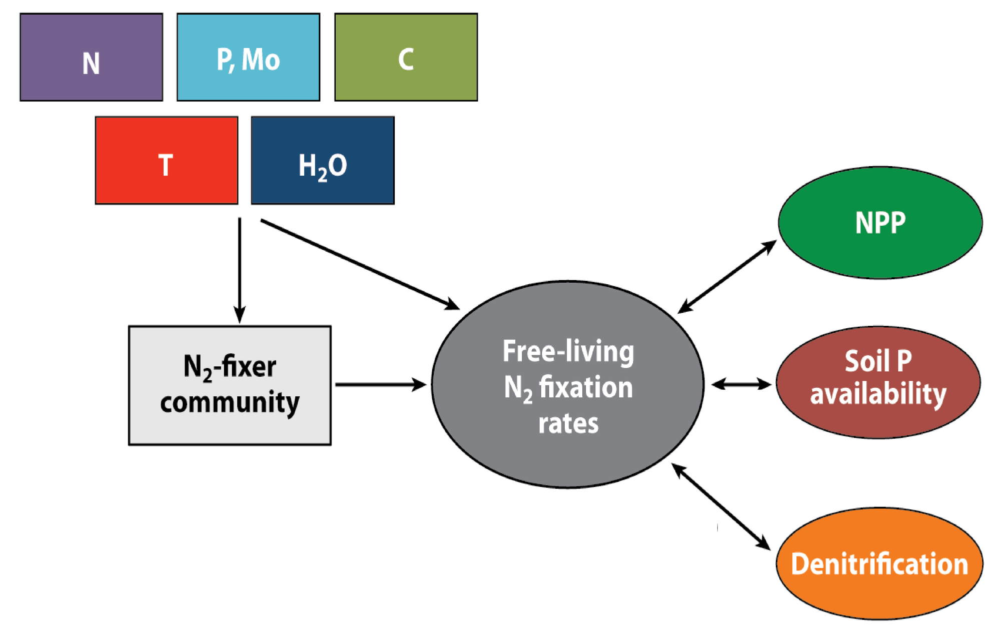

Fig. 1. Various factors have been shown to regulate N_2 fixer activity. P, Mo, N, C (quality and availability), temperature (T), and moisture (H_2O) have all been shown to regulate free-living N_2 fixation rates in terrestrial ecosystems, but the relative importance of any given factor is ecosystem specific. (Reed et al. 2011)

Soil, weather, and fire history variables were evaluated to determine the best predictors of free-living N_2-fixer activity across a local gradient in fire history of a grassland. We predicted that recent fire would increase soil nitrogen and phosphorus, and the activity of a functional gene for N_2 fixation (*nifH*) would be positively correlated with phosphorus and negatively correlated with nitrogen.

Methods

Using qPCR, we measured *nifH* DNA and mRNA as an analog for N_2 fixation. N_2 fixation has been positively correlated with the copy number of ***nifH*** (**nitrogenase functional gene**) DNA (r^2= 0.35, 0.81)(Reed et al. 2010, Wakelin et al. 2009) and mRNA (r^2= 0.72, 0.84) (Bürgmann et al. 2003). Analyses were then performed to determine the best predictor of variation in *nifH* copy number.

We sampled 18 plots from a mixed-grass prairie site in the Northern Great Plains. Plots were sampled five times from September 2011 - August 2012 (Fig. 2) producing 90 samples (18 × 5).

Predictor variables included 21 soil properties, two weather variables, and two fire history variables.

Predictor variables

1. *Soil chemical properties*: boron, calcium, calcium base saturation, cation exchange capacity, copper, iron, magnesium, magnesium base saturation, manganese, nitrate, organic matter content, pH, phosphorus (weak and strong Bray), potassium, potassium base saturation, sodium, sodium base saturation, soluble salts, sulfur, and zinc
2. *Weather variables*: mean temperature and total precipitation 30 d prior to sampling
3. *Fire history variables*: return interval (1.5, 3, 6, and ca. 20 yrs) and time since fire (29 times since fire ranging from 0.16 to 21.0 yr)

Results

• As a regional drought progressed (Fig. 2B,C), the copy number of *nifH* DNA and mRNA decreased dramatically (Fig. 2A).

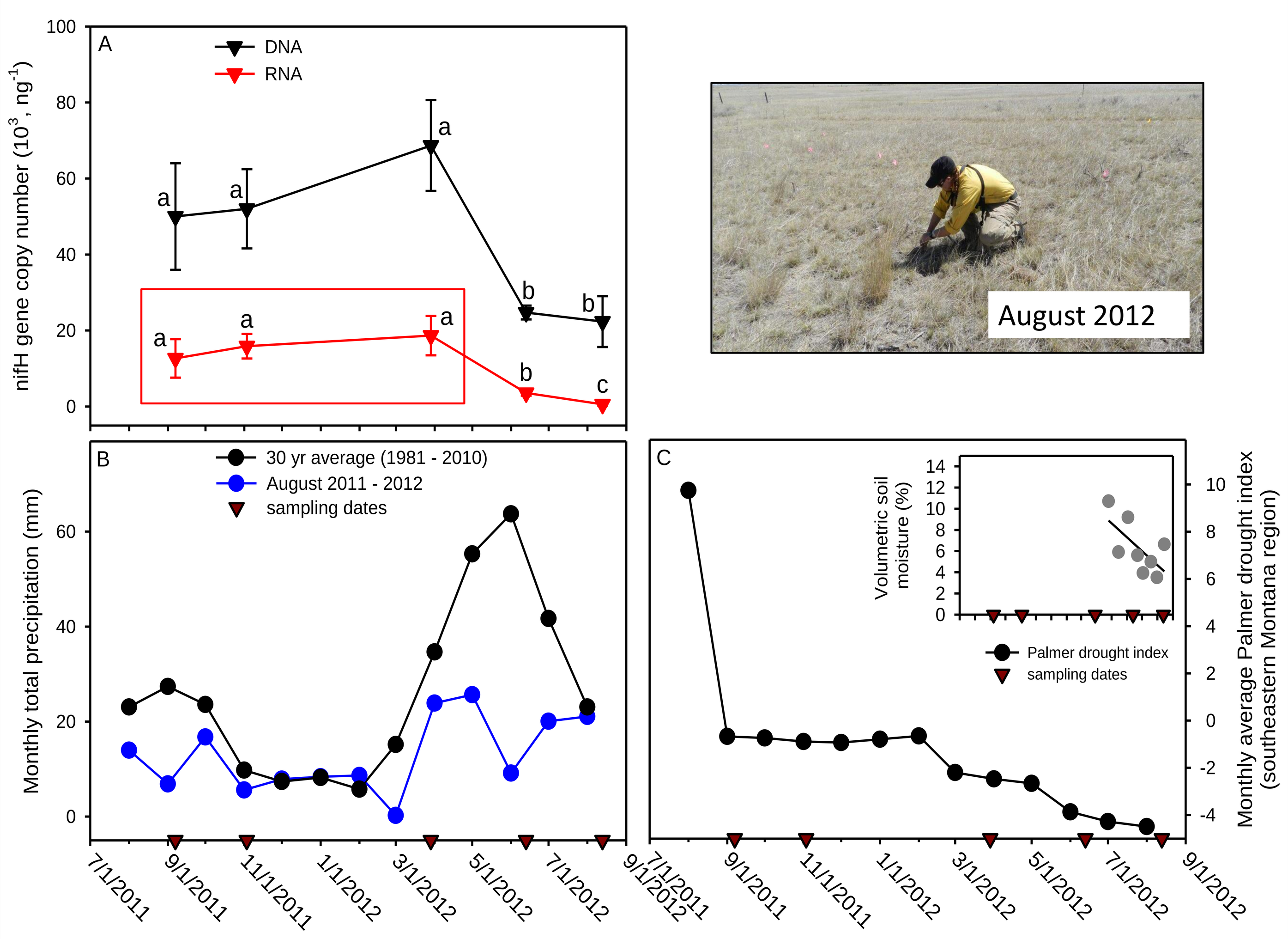

Fig. 2 Temporal variation in monthly measures of nitrogen-fixing functional gene (*nifH*) copy number (with ± 95% CI) from soil samples (A), total precipitation (B), and the Palmer drought index (C) from August 2011-2012. The red box indicates the subset of data used in subsequent analyses (Fig. 3).

Predictors of N_2 fixer activity

*We expected time since fire, nitrate, and phosphorus to be strong predictors of N_2 fixer activity (*nifH *mRNA).*

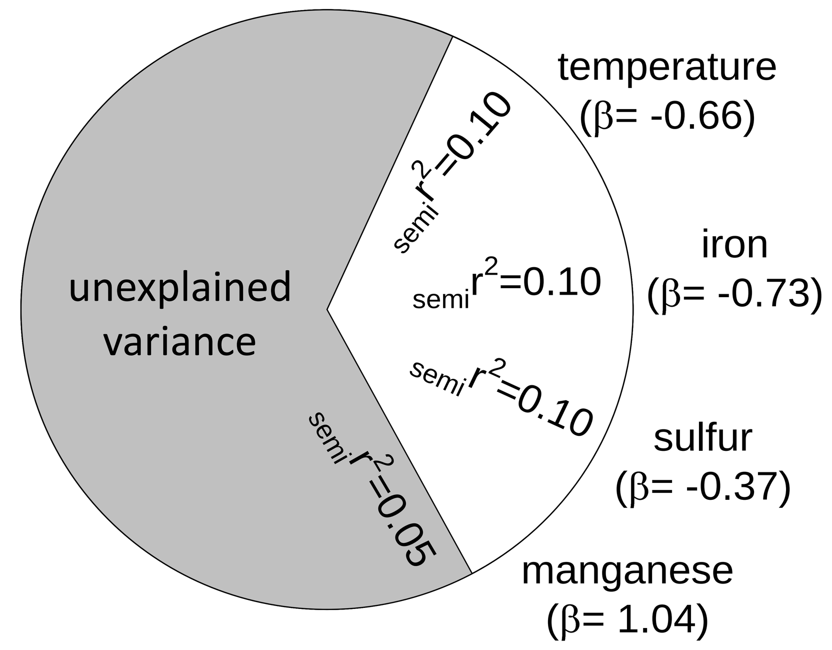

Fig. 3. Variation in *nifH* mRNA copy number explained by temperature and three soil properties (R^2=0.35, area shaded gray). Best model selection based on BIC scores.

Displayed are the squared semi-partial coefficients of determination which characterize the relationship between the dependent and independent variable after the contributions of the other independent variables have been removed and standardized beta coefficients which standardize the parameter estimates correcting for variation in scales per parameter.

• Variation in *nifH* mRNA was best explained by a model ($F_{4,43}$ = 5.9, P<0.001, R^2= 0.35) with temperature and three soil properties (Fig. 3). Evaluation of the $_{semi}r^2$ which better (but not fully) accounts for variable collinearity revealed that temperature, iron, and sulfur contribute equally and more than manganese in explaining variation in *nifH* mRNA.

Conclusions

• Drought was a main predictor of temporal variation in *nifH* activity (Fig. 2).

• We failed to support our prediction that time since fire, nitrate, or phosphorus were useful predictors of *nifH* (Fig. 3).

• Several soil properties (Fig. 3) were moderately useful predictors of *nifH* variation. However, associations were complex due in part to collinearity among soil properties [e.g. manganese correlated with sulfur (r= 0.42), iron (r=0.80), and CEC (r=-0.53)].

References

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