Soil nitrogen cycling in riparian forests: Driver of non-native plant invasion?

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ABSTRACT

Increased nitrogen (N) availability has altered the species composition and productivity of many ecosystems by replacing native plant species with N-demanding or N-responsive species. These results, combined with the fact that N availability within river-floodplain systems is rising worldwide, suggest that increased riparian plant species invasion may be facilitated by differences in the relative abilities of native and non-native species to utilize nutrients. Several species of the genus *Tamarix* L. (salt cedar) are invading many riparian corridors of the southwestern United States that were once dominated by species of the genus *Populus* L. (cottonwood). These systems are co-limited by water and nitrogen. Many factors that facilitate *Tamarix* invasion are well known, particularly in relation to water use efficiency. Whether *Tamarix* exhibits greater nitrogen resource use efficiency over that of native species, however, merits further research. Preliminary data show that soil N availability is significantly higher in *Populus* vs. *Tamarix* study sites. However, data on extracellular root enzyme activity and foliar C:N:P ratios do not fully elucidate whether elevated soil nitrogen availability is due to higher rates of N mineralization at *Populus* sites or increased N uptake at *Tamarix* sites. Data to be analyzed regarding soil N mineralization potentials and experimental 15N uptake by *Populus* and *Tamarix* roots will serve to clarify the mechanisms behind trends seen to date.

INTRODUCTION

- Native riparian forests of NM, AZ, & CA are ecosystems in decline.
- > 1000 km in contiguous 48 US states severely altered for hydropower, navigation, or water storage, resulting in reduced variability in river flow and fewer riparian flood events
- Last major floods on the middle Rio Grande, NM: Spring of 1941 & 1942 (~ 700 $m^3 s^{-1}$)
- Flood timing and magnitude and rate of draw down is critical to the establishment of native vegetation. Flooding also delivers nutrients to nutrient-poor floodplains of the semi-arid Southwest and drives decomposition and nutrient cycling.
- Between 1935 and 2002, non-native riparian plant land cover has increased by 3066 ha (2048 ha increase in *Tamarix*)
- Riverine corridors are prone to invasion by non-native plant species. What is the role, if any, of soil N availability in promoting plant invasion?
- In 2000, levels of NO_3-N in the Middle Rio Grande were on the order of 1.5 – 2.0 ppm (as opposed to <0.5 ppm in other parts of the river); elevated concentrations are attributed to effluent from wastewater treatment plants, agricultural run-off and atmospheric deposition
- Increased N availability has altered the species composition in a variety of ecosystems and has often favored N-responsive or N-demanding species over species adapted to nutrient-poor soils
- Evidence of competitive advantage by *Tamarix* seedlings over native plants has been shown to occur at very high levels of fertilization

OBJECTIVES & HYPOTHESES

The objectives of this study are to determine if soil N availability and N resource use differ between mature stands of *Populus deltoides* Bartr. ex Marsh. ssp. *wislizeni* (S. Wats.) Eckenwalder (Rio Grande cottonwood) or *Tamarix chinensis* Lour. (salt cedar) along the Rio Grande of New Mexico. If increased N availability is a driver of biological invasions within riparian ecosystems, the following hypotheses ought to be supported by empirical data:

Soils: (1) soil pools of inorganic N, (2) N mineralization potentials[1] and (3) available pools of organic N (proteins, free amino acids) will be greater in stands of *Tamarix* vs. *Populus*

Plant Physiology: *Tamarix* will demonstrate a competitive advantage over *Populus* via (4) lesser foliar C:N ratios, greater foliar N:P ratios, greater biomass:N ratios; (5) greater foliar NRA activity[1]; and (6) greater ^{15}N uptake[1] of NO_3^-, NH_4^+, or glycine relative to *Populus*.

Flood events occur intermittently (every 2-3 years) at half of the eight *Populus* and *Tamarix* study sites. The stated hypotheses will be tested both independently and in conjunction with the flood regime experienced by each study site.

[1] Data not shown.

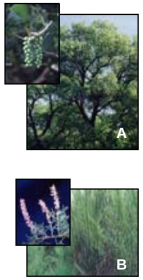

Figure 1. *Populus* tree and seeds (A) and *Tamarix* tree and flowers (B).

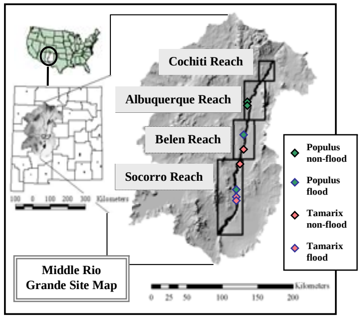

Figure 2. Map of study sites along the middle Rio Grande of NM.

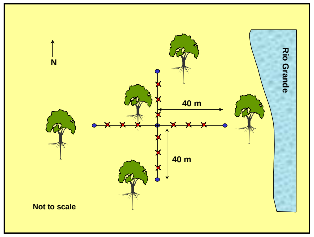

Figure 3. Map of experimental design at each study site. Blue circles represent groundwater wells. Soil samples were collected and homogenized at three points along each transect denoted by a red 'X'. Three study trees were selected along a perpendicular gradient from the river from which root and leaf samples were collected.

Table 1. Table of research components illustrated in poster and their and associated assays.

Research Component	Method
Inorganic N	2 N KCl extraction and reading on Technicon AutoAnalyzer II
Soil proteins	Bradford assay and spectrophotometer reading at 595 nm
Soil amino acids	Ninhydrin assay and spectrophotometer reading at 570 nm
Root enzyme activity	Extracellular enzyme assay and flourometer reading at 365 excitation and 460 emission
Leaf C:N:P ratios	Drying at 50ºC for 48 hr and reading of CN on Carlo Erba Elemental Analyzer; reading of Orthophosphate on Technicon AutoAnalyzer II

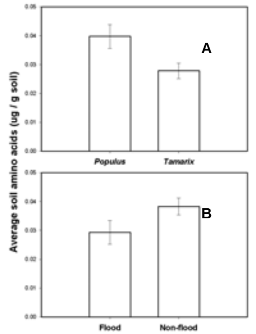

Figure 4. Average soil amino acids in *Populus* vs. *Tamarix* sites (2-way ANOVA: N = 8, df = 1, F = 5.24, p =0.033) (A) and in flood vs. non-flood sties (N = 8, ns) (B) ± 1 SE. No interaction effect exists between vegetation and flood type.

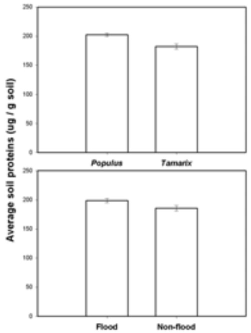

Figure 5. Average soil proteins in *Populus* vs. *Tamarix* sites (2-way ANOVA, N = 8, df = 1, F = 9.04, p =0.007) (A) and in flood vs. non-flood sties (N = 8, df = 1, F = 3.78, p = 0.066) (B) ± 1 SE. No interaction effect exists between vegetation and flood type.

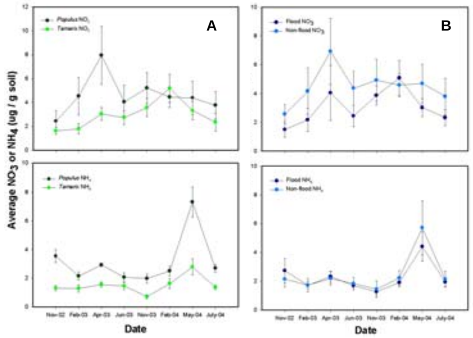

Figure 6. Average NO_3 (RMANOVA, N = 8, ns) and NH_4 (N = 4, F = 64.27, p = 0.001) ± 1 SE in *Populus* vs. *Tamarix* sites (Panel A) and in flood (N = 8, ns) vs. non-flood sites (N = 8, ns) (Panel B).

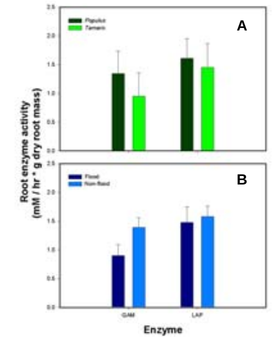

Figure 7. Average root enzyme activity of gleucine-7-amino-4-methylcoumarin (GAM) and leucine amino peptidase (LAP) in *Populus* vs. *Tamarix* roots (2-way ANOVA, N = 8, ns) (A) and in roots from flood vs. non-flood sites (N = 8, ns) (B) ± 1 SE.

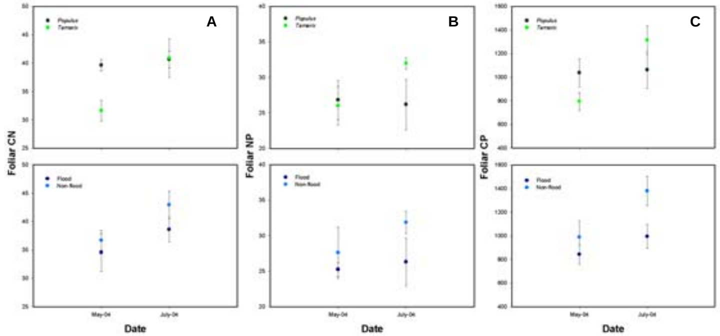

Figure 8. Foliar C:N ratios (Panel A), foliar N:P ratios (Panel B), and foliar C:P ratios (Panel C) ± 1 SE in *Populus* vs. *Tamarix* (upper) and flood vs. non-flood (lower) sites. N = 8 in all cases. No statistical analyses have yet been performed.

Table 2. Loadings of variables entered into a principal components analysis (PCA). One PCA factor explains 72.4% of the variance.

Variables	Component 1
Average NO_3	0.863
Average NH_4	0.911
Average amino acid	0.591
Average C:N[1]	-0.819
Average soil C:P[1]	0.974
Average N:P[1]	0.896
% of variance	**72.4**

[1] Data not shown

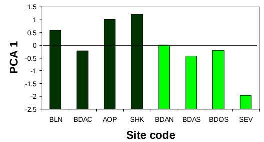

Figure 9. Values for PCA 1 that represent individual study sites. Dark green bars represent *Populus* sites. Light green bars represent *Tamarix* sites.

CONCLUSIONS

- Soil N availability is higher in *Populus* than *Tamarix* study sites, as evidenced by elevated quantities soil NH_4 (Fig. 6) and amino acids (Fig. 4). Overall average inorganic soil N also is significantly higher at *Populus* vs. *Tamarix* sites (data not shown). Whether N availability reflects higher mineralization rates at *Populus* sites or higher plant uptake at *Tamarix* sites cannot be determined until further plant physiological and soil N mineralization potential data is analyzed.
- Flood regime plays little to no role in soil N availability between 2003 – 2004 as evidences by non-significant differences in mean soil NO_3, NH_4, amino acids, or proteins.
- Principle component analysis (PCA) of soil N parameters resulted in 73.4% of variance explained by one PCA factor (Table 2). This factor represents an overall nutrient fertility gradient that will later be regressed with another PCA factor developed for parameters of plant physiology.
- Root enzyme activity for gleucine-7-amino-4-methylcoumarin (GAM) and leucine amino peptidase (LAP) is comparable across vegetation types and flood regime.
- *Populus* samples vary little with respect to C:N:P ratios between May and July 2004. Elevated N:P ratios in *Tamarix* may reflect elevated N uptake by *Tamarix*. However, data from extracellular root enzyme activity suggest uptake rates are similar across vegetation types. Therefore, higher foliar N:P ratios in *Tamarix* appear to be driven by reduced P availability throughout the growing season, which is supported by trends in data across flood and non-flood sites. Experimental ^{15}N uptake by tree roots will help to clarify trends in foliar C:N:P ratios.

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