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# Effects of two nitrogen-fixing invasive plants species on soil chemical properties in south-central Chile

## Efecto de dos especies de plantas invasoras fijadoras de nitrógeno sobre las propiedades químicas del suelo en el centro-sur de Chile

Rafael A. García[1,3], Andrés Fuentes-Ramírez[2,3] & Aníbal Pauchard[1,3]

[1]Facultad de Ciencias Forestales. Universidad de Concepción. Casilla 160-C, Concepción, Chile.
[2]Departamento de Botánica. Facultad de Ciencias Naturales y Oceanográficas. Universidad de Concepción. Casilla 160-C, Concepción, Chile.
[3]Instituto de Ecología y Biodiversidad (IEB). Casilla 653, Santiago, Chile.
ragarcia@udec.cl

**RESUMEN**

Dos especies invasoras leñosas, *Acacia dealbata* y *Teline monspessulana* (Fabaceae), ampliamente distribuidas en el centro-sur de Chile, poseen la capacidad de fijar biológicamente el nitrógeno atmosférico y contribuir a la fertilidad del suelo. Se presentan evidencias de potenciales cambios ocasionados por estas especies en las propiedades químicas del suelo en áreas altamente degradadas de la Región del Bío-Bío, Chile.

Invasive plants can modify many factors within the ecosystems, including the physical, chemical and biological properties of the soil. Studies have focused mostly on those species capable of changing the nitrogen cycle in the soil (e.g. Jeffrey & D'Antonio 2004, Liao *et al.* 2008). These changes are most notorious when the species are woody plants and they have the capacity for fixing atmospheric nitrogen (Liao *et al.* 2008). Two of the most invasive species capable of fixing nitrogen in south-central Chile are *Acacia dealbata* Link and *Teline monspessulana* (L.) K.Koch (both Fabaceae) (Quiroz *et al.* 2009). Invasion of these species have been also associated with a decrease in native species diversity (Bossard 2000, Fuentes-Ramírez *et al.* 2010) and changes in the fire regime (Pauchard *et al.* 2008). The rapid expansion of these species in south-central Chile is expected to impact the soil nitrogen balance and also may change others chemical properties of soils, which could affect the neighbor species performance, or even promote the invasion across the landscape.

Changes brought by these Fabaceae species on the chemical properties of soil were measured through sampling of the first four centimeters of the mineral soil in four study settings: 1) *Teline* growing next to anthropogenic grasslands (disturbed areas covered mainly with non-native grasses and forbs, usually abandoned crops), 2) *Teline* growing next to native forest fragments, 3) *Acacia* growing next to anthropogenic grasslands, and 4) *Acacia* growing next to native forest fragments. Soil samples were taken in three different sites for each study setting in the Bío-Bío Region (Fig. 1). At each study site, we collected two soil samples at each of three conditions: 1) the edge between the invaded area and the surrounding matrix ("edge"), 2) at 10 meters inside the invasive population (*Teline* or *Acacia*), and 3) 10 meters inside the surrounding matrix (grassland or native forest). Each sample was a mixture of four sub-samples collected at the four corners of a 1m$^2$ plot. For all samples we determined pH, organic matter content (%), nitrogen concentration (nitrate and ammonium content), phosphorus available (P), and Potassium (K). Samples were analyzed in the Laboratory of Analysis of Soils and Plants, Universidad de Concepción. To determine statistical differences in the concentrations of the soil nutrients, we analyzed separately each species in each study condition, using a block design (sites as blocks) and a posteriori Tukey test for assessing the significance level.

We found a trend of increasing concentration of available nitrogen ($NO_3^- + NH_4^+$) from grasslands and native forests into *T. monspessulana* populations (Fig. 2). However, nitrate increasing was only statistically significant in the invader-grassland transition ($F = 142.37$; $p = 0.0002$). Ammonium concentration was higher in soils with *Acacia* presence than in those occupied by native forest ($F=9.51$; $p=0.0302$) (Fig. 3). In all sites and study conditions the ammonium concentration was higher (between 55 and 81%) than nitrate concentration. Soils occupied by *A. dealbata* populations, which grow next to anthropogenic grasslands, had a higher K concentration on its interior than those in the surrounding matrix (Table I). Furthermore, *A. dealbata* soil presents pH values significantly more acid than native forest soil.

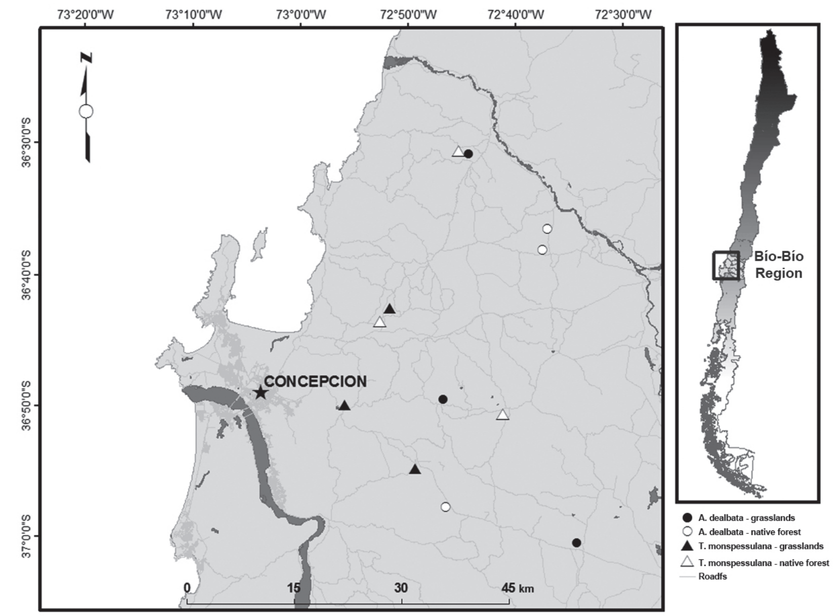


Figure 1. Study area and sampling points in the Bío-Bío Region, Chile (36° S – 72° W).

Figura 1. Área de estudio y sitios de recolecta en la Región del Bío-Bío, Chile (36º S – 72º W).

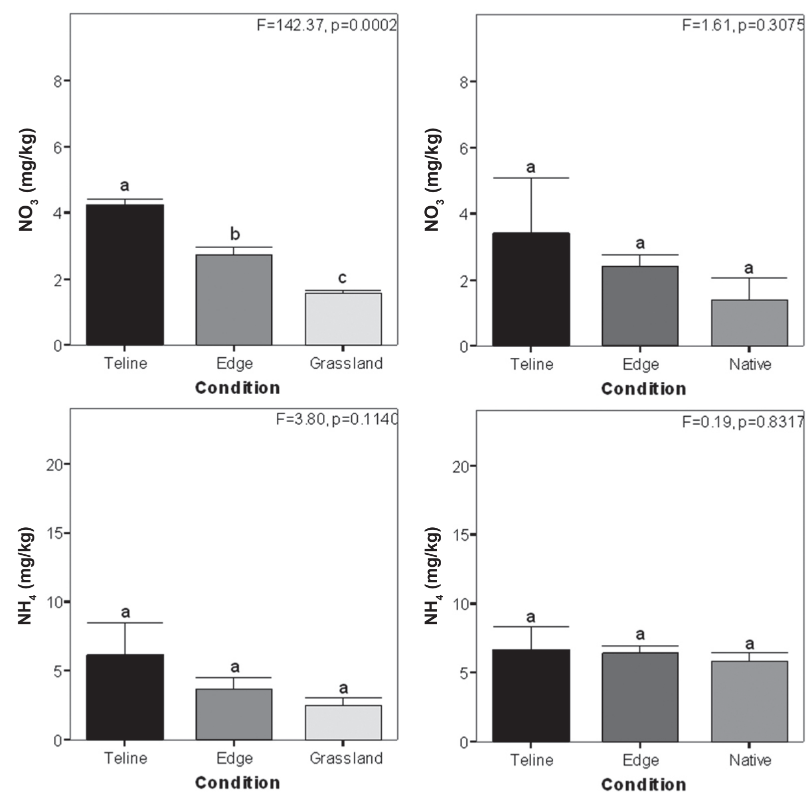


Figure 2. Concentration (+SE) of NO3- (top panels) and NH4+ (bottom panels) along the gradient *Teline*-grassland (left panels) and *Teline*-native forest (right panels). Different letters indicate significant differences between conditions (Tukey test, p<0.05).

Figura 2. Concentración (+EE) de NO3- (superior) y NH4+ (inferior) a lo largo del gradiente *Teline*-pradera (izquierda) y *Teline*-bosque nativo (derecha). Letras distintas indican diferencias significativas entre las condiciones (Test de Tukey, p< 0,05).

Our findings suggest that the effect mediated by the invader upon the nitrogen availability in the soil is variable and site-specific, and probably depends on the amount and availability of nitrogen or phosphorus below ground (Haubensak *et al.* 2004). *Acacia dealbata* can change the chemical properties of invaded soils of pine forest, shrubland and grassland, leading significant increasing of the N, C, exchangeable P and organic matter content (Lorenzo *et al.* 2010). Other invasive Australian acacias (e.g. *A. saligna* (Labill.) H.L.Wendl. and *A. longifolia* (Andrews) Willd.) also produce an increasing of the nitrogen concentration, that can even affect the chemical properties of water below ground and the soil microorganisms communities (Marchante *et al.* 2008, Le Maitre *et al.* 2011). Furthermore, invasive nitrogen-fixing species such as *Cytisus scoparius* (L.) Link (Fabaceae), are associated with a variable increase of the total nitrogen of the soil, and a decrease of the carbon/nitrogen ratio in an invasive gradient (Haubensak & Parker 2004).

The high variation of the soil nutrient contents in the study area limits the possibilities of distinguishing the direct effect of these two invasive species from other confounding factors such as previous land-use or disturbances. However, the trend into higher nitrogen content on invaded soils is considerable for both, *T. monspessulana* and *A. dealbata*. Further research is needed to understand the overall impact of these Fabaceae species in soil chemical properties, and thus, understand how these species may be altering ecosystem processes.

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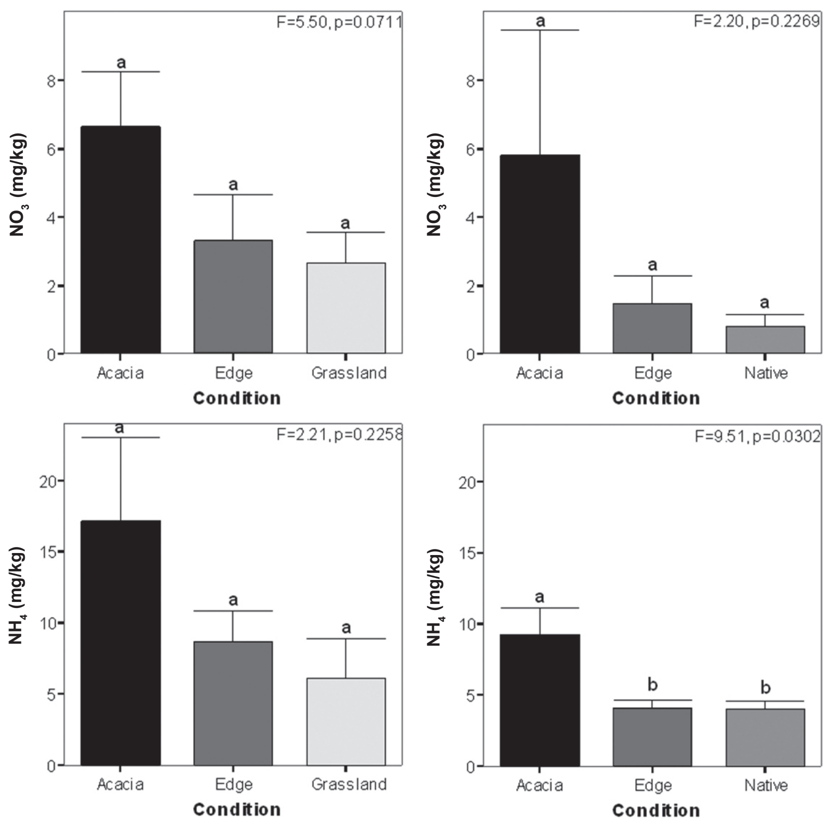


Figure 3. Concentration (+SE) of NO3- (top panels) and NH4+ (bottom panels) along the gradient *Acacia*-grassland (left panels) and Acacia-native forest (right panels). Different letters indicate significant differences between conditions (Tukey test, p<0.05).

Figura 3. Concentración (+EE) de NO3- (superior) y NH4+ (inferior) a lo largo del gradiente *Acacia*-pradera (izquierda) y Acacia-bosque nativo (derecha). Letras distintas indican diferencias significativas entre las condiciones (Test de Tukey, p< 0,05).

TABLE I. Values (+SE) of pH, organic matter (OM), P available and K concentration along the invaded gradient into the matrix in conditions *Teline*-grassland, *Teline*-native forest, *Acacia*-grassland, and *Acacia*-native forest (Tukey test, p<0.05).

TABLA I. Valores (±EE) de pH, Materia orgánica (OM), concentración de P disponible y K a lo largo del gradiente invadido a matriz en sitios con *Teline*-pradera, *Teline*-bosque nativo, *Acacia*-pradera y *Acacia*-bosque nativo (Test de Tukey, p<0,05).

| | *Teline* | | | | EDGE | | | | GRASSLAND | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 5,5 | ± | 0,1 | n.s | 5,4 | ± | 0,1 | n.s | 5,6 | ± | 0,1 | n.s |
| OM % | 4,9 | ± | 0,2 | n.s | 3,9 | ± | 0,8 | n.s | 1,9 | ± | 0,9 | n.s |
| P mg/kg | 5,8 | ± | 0,3 | n.s | 4,6 | ± | 1,1 | n.s | 2,3 | ± | 1,3 | n.s |
| K mg/kg | 194,7 | ± | 20,4 | n.s | 198,2 | ± | 31,3 | n.s | 180,4 | ± | 27,0 | n.s |
| | *Teline* | | | | EDGE | | | | NATIVE | | | |
| pH | 5,7 | ± | 0,1 | n.s | 5,6 | ± | 0,1 | n.s | 5,6 | ± | 0,1 | n.s |
| OM % | 4,3 | ± | 0,2 | n.s | 3,7 | ± | 0,4 | n.s | 3,9 | ± | 0,6 | n.s |
| P mg/kg | 9,0 | ± | 1,7 | n.s | 5,8 | ± | 0,7 | n.s | 5,3 | ± | 0,5 | n.s |
| K mg/kg | 162,1 | ± | 19,8 | n.s | 179,9 | ± | 16,5 | n.s | 181,7 | ± | 27,4 | n.s |

| | *Acacia* | | | | EDGE | | | | GRASSLAND | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 5,4 | ± | 0,1 | n.s | 5,5 | ± | 0,2 | n.s | 5,8 | ± | 0,3 | n.s |
| OM % | 4,9 | ± | 1,2 | n.s | 2,3 | ± | 0,2 | n.s | 1,4 | ± | 0,4 | n.s |
| P mg/kg | 6,5 | ± | 3,0 | n.s | 3,5 | ± | 1,6 | n.s | 2,3 | ± | 0,7 | n.s |
| K mg/kg | 227,0 | ± | 38,9 | **a** | 159,8 | ± | 30,1 | **ab** | 101,5 | ± | 12,2 | **b** |
| | *Acacia* | | | | EDGE | | | | NATIVE | | | |
| pH | 5,6 | ± | 0,1 | **b** | 5,9 | ± | 0,1 | **a** | 6,0 | ± | 0,1 | **a** |
| OM % | 4,2 | ± | 0,6 | n.s | 3,7 | ± | 0,5 | n.s | 4,3 | ± | 0,4 | n.s |
| P mg/kg | 2,9 | ± | 0,6 | n.s | 3,5 | ± | 0,5 | n.s | 3,3 | ± | 0,6 | n.s |
| K mg/kg | 221,0 | ± | 26,5 | n.s | 199,0 | ± | 12,2 | n.s | 247,4 | ± | 14,1 | n.s |

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