From Forest Nursery Notes, Summer 2009

**106. Environmental factors affect the spatial arrangement of survival and damage of outplanted *Nothofagus dombeyi* seedlings in the Chilean Andes.** Soto, D. P., Donoso, P. J., Uteau, D., and Zuniga-Feest, A. Interciencia 34(2):100-105. 2009.

# ENVIRONMENTAL FACTORS AFFECT THE SPATIAL ARRANGEMENT OF SURVIVAL AND DAMAGE OF OUTPLANTED *Nothofagus dombeyi* SEEDLINGS IN THE CHILEAN ANDES

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*SUMMARY*

*Mortality patterns were analyzed in a one-year old* Nothofagus dombeyi *plantation at mid-elevation in the Chilean Andes. Ripley's univariate function was used to detect spatial patterns of mortality and damage (as reflected in crown dieback) of seedlings by assigning them into four categories: no crown damage, 1/3 of the crown damaged, 2/3 of the crown damaged and dead. Through correspondence analysis, variables (plant attributes, topography, weed competition, neighboring vegetation and fertilization) that could affect mortality were tested. At the end of the first growing season 67% of the seedlings survived, and by the end of the following dormant season only 37% were alive. Mortality patterns were random for seedlings with 1/3 of the crown damaged, and clustered for all other categories. Environmental variables with the greatest influence on mortality were increasing distance to a neighboring 10m tall plantation, absence of tall vegetation cover and convex micro-topography. Results suggest that large temperature oscillations with events of freezing temperatures (defined as the reported lethal temperature for 50% of its leaves) during the growing season, and severe frost during the dormant season, were the main causes of mortality and damage. The convenience of providing seedlings with some shelter when outplanted, or with an appropriate cold-acclimation treatment to resist low freezing temperatures when outplanted in open fields in harsh cold regions of the south-central Andes is discussed.*

Plantations with native tree species in Chile are scarce, despite the fact that the Forest Service has promoted them for more than a decade. The three most widely planted trees are exotic (*Pinus radiata* [D. Don], *Eucalyptus globulus* [Labill], and *E. nitens* [Deane & Maiden]). Among native trees, several *Nothofagus* species seem to be the most promising. According to the last agricultural census there are ~4000ha of *Nothofagus* plantations in Chile, a rather small area that can be the result of a lack of high-quality seedlings, a poor knowledge about the plantation silviculture for these species, and/or a general belief that native species have low productivity. The technology to produce high-quality bare root and containerized seedlings is available (Donoso *et al.*, 1999; 2006; Bustos *et al.*, 2008), and there is increasing knowledge about the silvicultural treatments to be applied to *Nothofagus* plantations. It was shown that low elevation *Nothofagus* plantations can achieve high productivity rates (Donoso *et al.*, 1993, 1999, 2005, 2006). Unfortunately, transference and adaptation of this knowledge has been poor, and there are many questions about the fate of the plantations established at mid- and high elevations, where only few results have been reported (Donoso *et al.*, 1993). Mean growth rates of 16-29$m^3 \cdot ha^{-1}$ per year have been reported for some *Nothofagus dombeyi* ([Mirb.] (Oerst)) plantations (Donoso *et al.*, 1993, 1999, 2006), although these have been established without special site preparation treatments (tillage, herbicide, fertilization).

*N. dombeyi* is a pioneer tree species that colonizes sites that have been affected by large-scale disturbances such as fire, landslides or wind (Donoso, 1993; Veblen *et al.*, 1995; Donoso *et al.*, 2006). In general, the species has been reported as highly resistant to abiotic stress such as low temperatures, high light intensity,

**KEYWORDS / Abiotic Stress / Border Effects / Freezing Temperatures / Ripley's Function / Regeneration / Vegetation Cover /**
Received: 08/27/2008. Modified: 01/17/2009. Accepted: 01/21/2009.

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and drought (Alberdi, 1995; Reyes-Diaz *et al.*, 2005; Piper *et al.*, 2007), which allow it to grow in areas exposed to full sunlight, where periods of summer drought and extreme temperatures can occur (Alberdi *et al.*, 1985; Weinberger, 1973). The good adaptation of *N. dombeyi* growing in natural conditions that are marginal for most other native tree species (500-1000masl), allow to expect that plantations with this species and under these conditions should have good rates of growth and survival. However, the more severe climatic conditions at these elevations suggest that the behavior of these plantations can differ from that seen at lower elevations, especially in the direction of having lower growth and survival rates when established in the open field. To test this, a plantation was established in a site considered as marginal (>600masl in the Chilean Andes) for forest production of rapid growth species. It was established in a south-aspect open field where herbicide was applied in the plantation lines and plants were fertilized with different doses. After one growing season this plantation suffered high mortality rates. One aim of the present work was to study the spatial pattern of mortality and crown damage that took place in the plantation; another aim was to explore the causes for low survival and crown damage by studying the effects of local (low) and surrounding (tall) vegetation, micro- and macro-topography, fertilization and seedling morphology on seedling mortality.

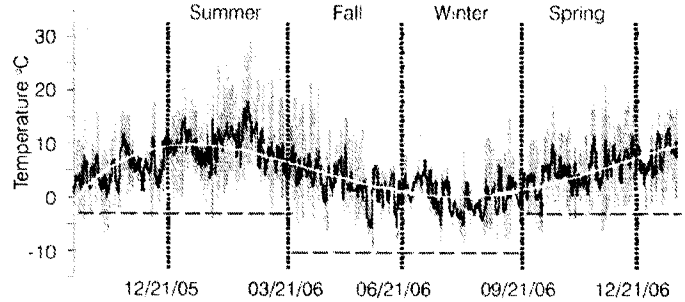


Figure 1. Temperatures registered by a Datalogger DIVER (Eijelkamp®). Black line: daily average, white line: a 4th order polynomial model fitted to the average values ($r^2$= 0.593, $P$<0.001), grey line: daily temperature oscillation, and horizontal lines: $LT_{50}$ for *N. dombeyi* in the growing and dormant seasons (*sensu* Alberdi *et al.*, 1985).

## Study site

The study was carried out in the Valdivian Andes of Chile (39°35'S, 72°05'W) at 620masl in San Pablo de Tregua, an experimental forest belonging to the Universidad Austral of Chile. The plantation was established on a south facing slope of an abandoned open field with a 10m tall *Nothofagus nervosa* plantation and shrubby vegetation on its northern side. The region has a coastal oceanic climate according to Köppen and a Mediterranean influence, with short and dry summers (Dec-Mar) and humid winters (Jun-Sept). The annual precipitation, mostly rainfall, ranges between 4000 and 5000mm (Neira, 2005) and is associated with westerly and northerly winds (Schlatter *et al.*, 1995). Mean annual temperature is 11°C, that of the coldest month (August) is 5°C and that of the warmest one (February) is 16°C. The number of annual frosts is 30-50, concentrated from August through September. A Datalogger DIVER (Eijelkamp®) was installed to record temperatures in the perimeter of the plantation at 1.5m above ground. Data points were recorded every hour from 10/1/2005 to 01/13/2007.

Soils at the plantation site are derived from modern volcanic ashes (Acrudoxic hapludand), well structured, with a Pumice horizon over basaltic-andesitic rocks (CIREN, 1999). The texture is medium through the entire profile, rich in thin sand on the surface and clay in the lower profile. In terms of fertility the most important characteristics are a high water retention capacity (>250mm in 1m depth), good infiltration, high organic matter content and total N (0.97 ±0.07%), and a suitable C/N relation of 11.6 ±0.3. However, these soils are poor in bases and P (3.5 ±0.6mg·kg$^{-1}$; Donoso *et al.*, 2007). The main limitations are rapid superficial moisture loss, high P retention, high Al levels (49 ±6%) due to the presence of alophan, and wind erosion (Schlatter *et al.*, 1995).

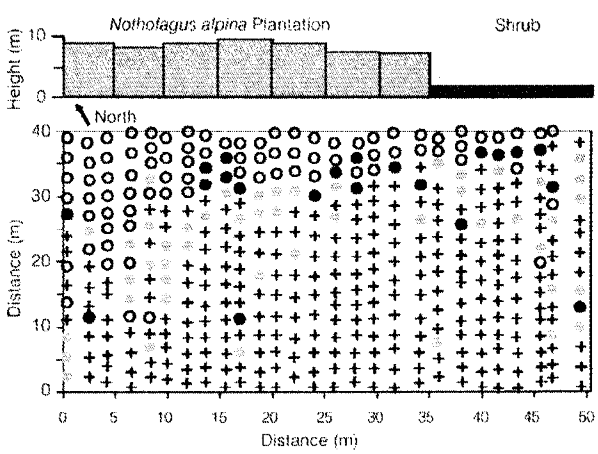


Figure 2. Spatial distribution of damaged trees in the study plot. Open circles shows the healthy seedlings, grey circles are seedlings with 1/3 of the crown damaged, black circles are seedlings with 2/3 of the crown damaged and crosses are dead seedlings. The upper histogram corresponds to the neighboring *Nothofagus nervosa* plantation and the shrubby vegetation.

## Methods

### *Characteristics of the seedlings and the plantation*

The *Nothofagus dombeyi* ([Mirb.] (Oerst)) seedlings were grown in 130cm$^3$ polyethylene containers using composted *Pinus radiata* bark as the substratum, and were fertilized with a slow-release (18-6-12) fertilizer (Osmocote®; 5kg per m$^{-3}$). The seed source was local, from San Pablo de Tregua. The containers were sown during the first week of September in a greenhouse and moved outdoors, under a 50% mesh, at the end of November, when N-based fertilization was initiated, and finally hardened during the last month of the growing season (February) by taking the mesh away and eliminating fertilization with N in favor of K. The seedlings selected for the study were 35-45cm tall with a 3-4mm root collar diameter when outplanted at the end of October of the following year (see Bustos *et al.* (2008) for further seedling characteristics). A spacing of ~2×2.5m was used throughout the 1ha plantation. Weeds were controlled by applying 4l of glyphosfate and 3.5l of Simazine per ha on 1m wide strips immediately after planting.

### *Sampling*

One growing season after planting, and past the first winter and the first half of the second year spring, a 2000m$^2$ (40×50m) area was sampled. In this area height, root collar diameter and the X and Y coordinates of each one of 410 seedlings were recorded. Between outplanting and sampling, freezing temperatures occurred several times; just for a few hours a small number of days during the first growing season and even for entire days numerous times during the dormant season (Figure 1).

At the end of the first growing season (May) 67% of the seedlings were alive; they had reached an average collar diameter of 7.3cm and an average height of 75cm. At the beginning of the following spring (October) only 37% of the outplanted seedlings had survived; that is, 55% of the seedlings that were alive at the end of the first growing season (Figure 2). Therefore, it was decided to divide seedlings into four categories related to their survival and damage status: undamaged (the whole crown undamaged), slightly damaged (1/3 of its crown dead), seriously damaged (2/3 of its crown damaged) and dead.

*Statistical analyses*

The X and Y coordinates of each seedling in the sampled area were incorporated into the SpPack software (Perry, 2004) to use Ripley's K(t) function (Ripley, 1977) to represent the categories of seedling conditions. The interpretation was made according to L(d)-d against the d distance, which fits to the zero value. Therefore, the spatial pattern is grouped when L (d)-d is significantly (P<0.05) >0, and regular if L (d)-d is significantly <0 (Rozas and Camarero, 2005; Salas *et al.*, 2006).

Each of the five factors that can have an effect on seedling conditions have different levels (Table I). The seedling variables (Rock *et al.*, 2004) considered were crown form, height, and fertilization (high, medium and no fertilization, as reported in Donoso *et al.*, 2007). The environmental variables were micro-topography (1m around the seedling), macro-topography (4m uphill and downhill from the seedling), weed cover (vegetation 1: <25% of the plant height; vegetation 2: 25-75% of the plant height; vegetation 3: >75% of the plant height). In addition, the type of vegetation (10m tall *N. nervosa* trees or 3m tall shrubs) in the north side of the plantation and the distance of individual plants to the edge were recorded. The five factors with their different levels were analyzed using correspondence analysis (CA) to represent spatial ordination (ter Braak, 1985). CA is a unimodal technique to organize series of categorical variables and non continuous data, allows detection of differences between two variables in a space of small dimensions and the interpretation of similarities and relations between categories. This allows the detection of dependences among variables (ter Braak, 1985; Jongman *et al.*, 1995).

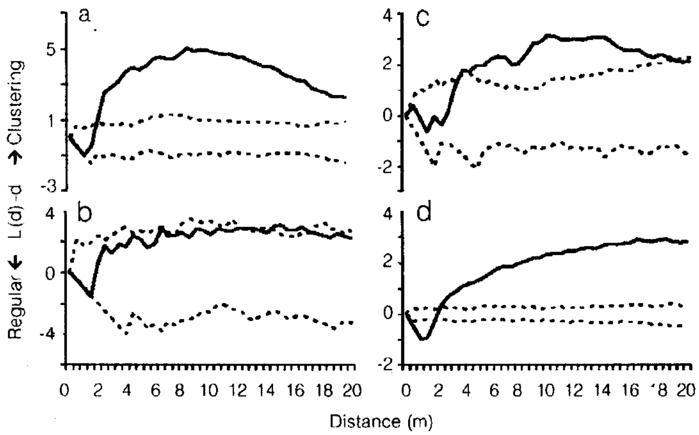


Figure 3. Univariate spatial point patterns of the K(t) Ripley's function. Dotted line: 95% confident interval; a: no crown damage, b: 1/3 crown damage, c: 2/3 crown damage, and d: dead plants.

TABLE I
VARIABLES STUDIED AS POTENTIALLY ASSOCIATED WITH TREE DAMAGE, AND NUMBER OF SEEDLINGS BY CATEGORY AND VARIABLE

| Group type | Variable | Category | Seedlings per category | % per category |
|---|---|---|---|---|
| Plant | Crown damage | 1. no | 84 | 20.4 |
| | | 2. 1/3 | 21 | 5.1 |
| | | 3. 2/3 | 48 | 11.7 |
| | | 4. Dead | 257 | 62.7 |
| | Crown Form* | 1. Monopodic | 193 | 47.0 |
| | | 2. Fork | 127 | 30.9 |
| | | 3. Multi-fork | 74 | 18.1 |
| | | 4. Dissolved | 16 | 3.8 |
| | Height class (cm) | 1. 0-50 | 60 | 14.5 |
| | | 2. 51-89 | 278 | 67.5 |
| | | 3. 90-125 | 73 | 17.8 |
| Topography | Micro-topography | 1. Flat | 150 | 36.6 |
| | | 2. Convex | 20 | 4.7 |
| | | 3. Concave | 240 | 58.6 |
| | Macro-topography | 1. Flat | 204 | 49.7 |
| | | 2. Convex | 73 | 17.8 |
| | | 3. Concave | 133 | 32.4 |
| Weed competition | Vegetation cover (%) 1** | 1. 0-5 | 12 | 2.9 |
| | | 2. 5-25 | 15 | 3.5 |
| | | 3. 25-50 | 56 | 13.6 |
| | | 4. 50-75 | 148 | 36.0 |
| | | 5. 75-100 | 179 | 43.7 |
| | Vegetation cover (%) 2** | 1. 0-5 | 381 | 92.8 |
| | | 2. 5-25 | 26 | 6.2 |
| | | 3. 25-50 | 2 | 0.5 |
| | | 4. 50-75 | 1 | 0.2 |
| | Vegetation cover (%) 3** | 1. 0-5 | 354 | 86.3 |
| | | 2. 5-25 | 38 | 9.2 |
| | | 3. 25-50 | 16 | 3.8 |
| | | 4. 50-75 | 1 | 0.2 |
| | | 5. 75-100 | 1 | 0.2 |
| Neighbor vegetation | Type of Border | 1. Plantation | 317 | 77.3 |
| | | 2. Shrub | 93 | 22.6 |
| | Distance to border (m) | 1. 0-12 | 174 | 34.8 |
| | | 2. 12-24 | 59 | 39.3 |
| | | 3. 24-36 | 39 | 25.8 |
| Fertilization | Fertilization (g per plant) | 1. 0 | 216 | 52.6 |
| | | 2. 110 | 67 | 16.3 |
| | | 3. 160 | 127 | 30.9 |

For details see Methods. * From Rock *et al.* (2004). ** Categories from Braun-Blanquet (Knapp, 1984).

## Results

*Distribution of seedling damage*

Seedlings with no crown damage, with 2/3 of the crown damaged and dead had a clustered distribution, except for the first 2-4m (Figure 3a, c, and d), as opposed to trees with 1/3 of the crown damaged, which showed a random distribution (Figure 3b).

*Factors associated with seedling damage*

The first three dimensions of the CA accumulated 53.9% of the overall variation. Dimension 1 represented 22.1% of the variation, and illustrates (Figure 4 and Table II) that plants with a poor crown form (highest values) are in the opposite side of fertilization and macro-topography (lower values), i.e. plants with a poor form were mainly those with least fertilization, in a rather flat macro-topography. Dimension 2 represented 18.8% of the variation and illustrates that plants with more crown damage are more strongly opposed to high values of macro-topography and of tall competing vegetation (Figure 4 and Table II), i.e. severely damaged plants were in flat macro-topography, and had low levels of surrounding tall competition. Also, the most damaged plants were those farther away from the neighboring *N. nervosa* plantation. Vegetation 1 and 2 and height had a low value in Dimensions 1 and 2, and thus they had no important effect on the variables of interest, i.e. crown form and damage. Figure 4 also shows that seedlings of poorer crown form were close to the border of the shrubby vegetation rather than the neighboring *N. nervosa* plantation and seedlings with less crown damage were those closer to the plantation border. Also, seedlings with poor crown form were associated with low damage.

TABLE II
COORDINATES AND WEIGHTS OF THE STUDIED VARIABLES AND VARIATION EXPLAINED BY THE CORRESPONDENCE ANALYSES

| Group type | Variables | Weight | Dimension 1 | Dimension 2 | Dimension 3 |
|---|---|---|---|---|---|
| Plant | Crown damage | 0.143 | -0.166 | 0.226 | -0.034 |
| | Crown form | 0.079 | 0.203 | 0.153 | 0.381 |
| | Height class | 0.090 | 0.061 | -0.094 | -0.063 |
| Topography | Macro-topography | 0.081 | -0.169 | -0.328 | 0.145 |
| | Micro-topography | 0.099 | 0.232 | -0.079 | -0.173 |
| Weed competition | Vegetation 1 | 0.184 | 0.038 | 0.008 | -0.037 |
| | Vegetation 2 | 0.048 | 0.111 | -0.028 | -0.030 |
| | Vegetation 3 | 0.053 | 0.201 | -0.169 | 0.012 |
| Neighbor plantation | Type of border | 0.054 | 0.170 | 0.136 | -0.073 |
| | Distance to border | 0.085 | -0.187 | 0.136 | -0.052 |
| Fertilization | Fertilization | 0.079 | -0.296 | -0.150 | 0.022 |
| Partial variation explained (%) | | | 22.07 | 18.79 | 13.09 |
| Cumulative variation explained (%) | | | 22.07 | 40.86 | 53.96 |

## Discussion

### *Low temperatures affect* N. dombeyi *survival*

In this study two-thirds of the original plantation was dead one year after being planted, when one growing and one dormant season had already gone by. This resulted in a final clustered distribution for most plants and spatial separation (repulsion) of dead and live plants. We suggest that the severe mortality was mainly caused by 1) the large temperature oscillations and some freezing events during the growing season that affected seedlings without a proper cold-acclimation period once outplanted, and 2) severe frosts during the dormant season that are likely to have affected plants that entered the dormant season with low vigor. We discard the possibility that mortality was due to poor seedling quality (except for the lack of cold acclimation) or improper seedling handling, since these type of seedlings (from the same nursery) have had high survival and growth rates in other areas, and this plantation was a highly supervised experiment. During the year of evaluation, daily temperature oscillations during summer were as high as 20°C, and 15°C during spring, while during the dormant season there were multiple frost events (Figure 1). The mortality was tempered in some parts of the plantation for several reasons, eventually causing the observed clustered distribution.

Seasonal changes highly influence cold resistance in many species (Öquist and Huner, 2003; González-Rodríguez *et al.*, 2005; Bannister, 2006). *N. dombeyi* is reported to be highly resistant to low temperatures, with a $LT_{50}$ (lethal temperature for 50% of its tissue) between -8 and -10.5°C during winter and between -1 and -3°C during summer (Alberdi *et al.*, 1985; Alberdi, 1995). These values are lower than the usual $LT_{50}$ of tree species in the temperate regions of the southern hemisphere, which vary between -4.9 and -8.4°C (Read and Hope, 1989; Bannister, 2006) but higher than those for other *Nothofagus* species that distribute to higher latitudes than *N. dombeyi* in Chile (Alberdi, 1995). Figure 1 shows that freezing temperatures were recorded throughout the year. During the first spring and summer, after seedlings had been outplanted in October, there were few moments with temperatures <-3°C, the $LT_{50}$ for leaves from natural seedlings (Alberdi *et al.*, 1985; Alberdi, 1995). These temperatures likely had an effect on the death of 1/3 of the plants registered immediately following the end of the first growing season. During the following fall and winter only in few occasions temperatures were found to be <-8°C, the $LT_{50}$ for winter leaves from natural seedlings (Alberdi *et al.*, 1985; Alberdi, 1995). This suggests that seedlings used for the plantation had a higher $LT_{50}$. The hardening treatment applied to the seedlings in the nursery was aimed to have more lignified seedlings, but that seemed not to be sufficient for seedlings to resist freezing conditions, since this was not a cold-acclimation treatment. Laboratory cold-acclimation treatments can be an option so as to be more successful in outplanting *N. dombeyi* seedlings under these conditions, allowing an increase of their frost resistance (Reyes-Díaz *et al.*, 2005). For instance, Read and Hope (1989) were able to increase the frost resistance of *N. cunninghamii* (a species from temperate rainforests of Southern Australia) through artificial hardening from an $LT_{50}$ of -7.8°C in unhardened seedlings to -11.4°C in hardened seedlings. In the present study seedlings did not have the possibility to go through neither an efficient natural acclimation period nor an artificial cold-acclimation treatment. In addition, high growth rates exhibited by the seedlings in the nursery during early spring (Sept-Oct) could have caused a lower accumulation of soluble carbohydrates, reducing the resistance of seedlings to the frosts they had to withstand during late spring and summer (*sensu* Alberdi, 1995; Reyes-Díaz *et al.*, 2005).

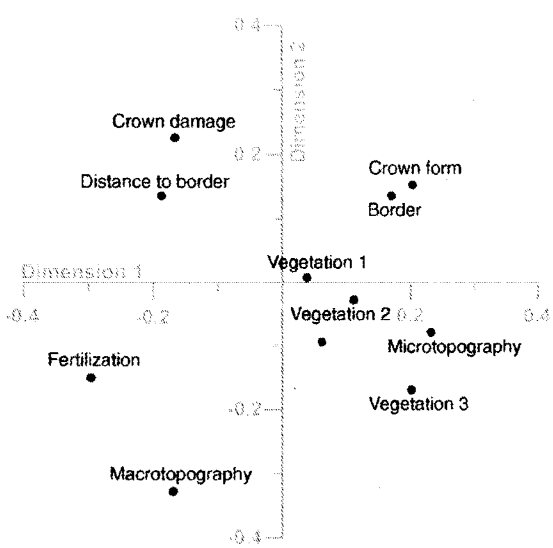


Figure 4. Relationships of the different variables evaluated through correspondence analysis for dimensions 1 and 2.

### *Positive effects of shelter and topography on survival of* N. dombeyi *seedlings*

Protection from the vegetation or weed cover and a 10m tall *N. nervosa* plantation in the northern edge of the plantation were the variables that explained most part of the variation in plant survival. Also, the accompanying vegetation (Vegetation 3>2>1) and micro-topography explained an important portion of survival variation. Less damage was associated with a greater cover of relatively tall accompanying vegetation (similar or taller than *N. dombeyi* seedlings). These results demonstrate that accompanying vegetation, which is usually considered to be competitive (Albaugh *et al.*, 2003; Nilsson and Örlander, 2003; Rubilar *et al.*, 2008), in some cases can have beneficial effects on the plantation, like ameliorating extreme temperatures (Bashant *et al.*, 2005; Donoso and Nyland, 2006). Seedlings showed less damage in concave surfaces. This kind of surface maintains a great amount of snow in the winter, preventing temperatures from falling below 0°C around the plant and on the soil surface (Donoso *et al.*, 2007). On the other side, fertilization caused a greater mortality probably for two reasons, toxicity in the case of the treatment with the highest doses (160g/pl; Donoso *et al.*, 2007) and decline in the richness of mycorrhizal fungi due to the increase in plant nutrients (*sensu* Godoy *et al.*, 1994). Therefore, outplanted seedlings could have reduced their resistance to drought stress (Fernández, 2005) and their tolerance to stressful initial conditions. Macro-topography was also related to a greater mortality, because concave areas presented higher mortality, probably due to the slow flow of cold winds through the gentle slopes.

*Management and restoration implications*

The shade-intolerant character of *N. dombeyi* (Veblen, 1985; Donoso, 1993; Donoso *et al.*, 2006; Donoso and Lusk, 2007) suggests that this species would tend to establish itself successfully in open fields lacking herbaceous or tree vegetation, like most pioneer fast-growing species (Bormann and Likens, 1979; Veblen and Alaback, 1996). This is the case at lower elevation, where survival rates are ~95% and growth rates are high (Donoso *et al.*, 1999, 2005, 2007), even on low-fertility sites (unpublished data). However, this does not seem to happen under more severe environmental conditions such as flat areas, pockets of cold air, and south-facing slopes with poor wind drainage at mid and high elevations in the Andean range. The results of the present study, although limited to one plantation, may bring up a warning about what to expect when outplanting *N. dombeyi* seedlings under difficult environmental conditions, especially considering that the magnitude and frequency of temperature oscillations at 400-600masl in the Andes have increased during the last 15 years (Villalba *et al.*, 2005), a condition that has caused massive mortality in *N. dombeyi* forests.

Landowners are becoming increasingly interested in planting *Nothofagus* trees because they are a promising option for management and restoration purposes, mainly at elevations >50masl. Knowledge of the critical factors to be taken into consideration for a successful reforestation program is important to decrease the current uncertainty about planting native species, one of the main reasons that explain the small area currently planted with *Nothofagus* trees in Chile. Establishing *N. dombeyi* plantations under environmental conditions similar to those in the present study has been more successful when conducted in the middle of vegetation strips (Álvarez and Lara, 2008), in gaps (unpublished data) or with lateral protection (like in this study). When planting in open fields like abandoned grasslands, we suggest maintaining the existing herbaceous or shrubby vegetation cover and, in the case of fertilizer application, to use moderate doses. It also seems necessary to provide seedlings with a cold-acclimation treatment and plant them at the end of the fall or during early winter, rather than in spring, as we did for this study. Professionals and landowners need to pay increasing attention on plant selection, date of planting, appropriate vegetation management and site preparation when embarked in plantation or restoration programs including *Nothofagus* trees at mid and high elevations in the south-central Andes of Chile.

## ACKNOWLEDGMENTS

The authors thank Oscar Thiers, Victor Gerding, Carlos Oyarzún and Heriberto Figueroa (Universidad Austral of Chile), Jonathan Barichivich (graduate student at University of East Anglia, UK), Christian Salas (PhD candidate at Yale University, USA), and the support received from FONDEF-CONICYT (Grant D04I1271).

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## FACTORES AMBIENTALES AFECTAN EL ARREGLO ESPACIAL DE LA SOBREVIDA Y DAÑO EN PLANTAS TRANSPLANTADAS DE *Nothofagus dombeyi* EN LOS ANDES CHILENOS

Daniel P. Soto, Pablo J. Donoso, Daniel Uteau y Alejandra Zúñiga-Feest

### *RESUMEN*

*Se analizaron los patrones de mortandad en una plantación de* Nothofagus dombeyi *de un año de edad a altura media en los Andes chilenos. La función univariada de Ripley fue utilizada para detectar patrones espaciales de mortalidad y daño de las plantas asumiendo cuatro categorías: sin daño en la copa, 1/3 de copa dañada, 2/3 de copa dañada y muerte. Las variables (atributos de la planta, topografía, competencia de maleza, vegetación vecina y fertilización) fueron probadas por análisis de correspondencia. Al final de la primera estación de crecimiento 67% de las plantas sobrevivieron y al final del siguiente período latente solo 37% sobrevivían. Los patrones de mortalidad fueron aleatorios en plantas con 1/3 de la copa dañada, y agrupados en las otras tres categorías. Las variables ambientales con la mayor influencia en mortalidad fueron: distancia a una plantación vecina de 10m de altura, ausencia de cobertura vegetal alta y microtopografía convexa. Los resultados sugieren que grandes variaciones de temperatura con eventos de congelamiento (definido como la temperatura reportada como letal para 50% de las hojas) en la estación de crecimiento y congelamiento severo en la estación de latencia fueron las causas principales de mortalidad y daño. Se discute la conveniencia de proteger las plantaciones transplantadas o de una aclimatación apropiada para resistir las bajas temperaturas en plantas transplantadas a campo abierto en zonas frías de los Andes chilenos sur-centrales.*

## FATORES AMBIENTAIS AFETAM O ARRANJO ESPACIAL DA SOBREVIDA E DANO EM PLANTAS TRANSPLANTADAS DE *Nothofagus dombeyi* NOS ANDES CHILENOS

Daniel P. Soto, Pablo J. Donoso, Daniel Uteau e Alejandra Zúñiga-Feest

### *RESUMO*

*Analisaram-se os padrões de mortalidade em uma plantação de* Nothofagus dombeyi *de um ano de idade a altura média nos Andes chilenos. A função univariada de Ripley foi utilizada para detectar padrões espaciais de mortalidade e dano das plantas assumindo quatro categorias: sem dano na coroa, 1/3 de coroa danificada, 2/3 de coroa danificada e morte. As variáveis (atributos da planta, topografia, competência de maleza, vegetação vizinha e fertilização) foram provadas por análise de correspondência. No final da primeira estação de crescimento 67% das plantas sobreviveram e no final do seguinte período latente somente 37% sobreviviam. Os padrões de mortalidade foram aleatórios em plantas com 1/3 da coroa danificada, e agrupados nas outras três categorias. As variáveis ambientais com a maior influência em mortalidade foram: distância a uma plantação vizinha de 10m de altura, ausência de cobertura vegetal alta e microtopografía convexa. Os resultados sugerem que grandes variações de temperatura com momentos de congelamento (definido como a temperatura relatada como letal para 50% das folhas) na estação de crescimento e, congelamento severo na estação de latência, foram as causas principais de mortalidade e dano. Discute-se a conveniência de proteger as plantações transplantadas ou de uma aclimatação apropriada para resistir as baixas temperaturas em plantas transplantadas a campo aberto em zonas frias dos Andes chilenos sul-centrais.*