Journal for Nature Conservation 22 (2014) 217–222

Contents lists available at ScienceDirect

Journal for Nature Conservation

journal homepage: www.elsevier.de/jnc

Effects of soil characteristics and exotic grass cover on the forest restoration of the Atlantic Forest region

Natacha Sobanski[1], Marcia C.M. Marques*

Laboratório de Ecologia Vegetal, Departamento de Botânica, Setor de Ciências Biológicas, Universidade Federal do Paraná, C.P. 19031, CEP 81531-980 Curitiba, Paraná, Brazil

ARTICLE INFO

Article history:
Received 29 November 2013
Received in revised form
30 December 2013
Accepted 8 January 2014

Keywords:
Abandoned pasture
Campomanesia xanthocarpa
Inga edulis
Seedling growth
Seedling survival
Soil compaction
Urochloa

ABSTRACT

The restoration of cattle grazing areas is a significant challenge for tropical forest restoration because of the effects of soil degradation and the competition between native trees and exotic grasses. To identify the major factors that impede forest restoration efforts, we examined the effects of different grass species, soil types and management techniques on the outcome of two species of tree seedlings in abandoned pastures. We compared the initial (12 months) seedling survival rates and growth of a fast-growing tree (*Inga edulis*) and a slow-growing tree (*Campomanesia xanthocarpa*), growing in Cambisols and Gleysols, using different management practices (till vs. no-till) and in the presence of two exotic grass species. Soil conditions were the most significant factor for influencing seedling performance, for both species; the grass species used in the pasture was less important. The flooding conditions in Gleysols may have potentially limited the seedling growth by affecting the height and diameter of *C. xanthocarpa*. Our results support the claim that soil conditions are the primary factors that negatively affect the growth and survival of native tree seedlings in abandoned farmlands. Restoration efforts that employ fast-growing native species should be chosen to increase the chances of restoration success in wet pasture areas.

Introduction

The conversion of tropical forests into agricultural land has resulted in high rates of biodiversity loss and has produced vast areas of abandoned pasturelands and secondary forests, altogether accounting for over 40% of the world's tropical forested area (Aide et al., 2000; Brown & Lugo, 1990). The development of pastures for cattle grazing has been a major contributor to this phenomenon. Considering that less than 5% of the world's remaining tropical rainforest has been designated as a protected area by the host country, these forested areas should be restored and augmented with native species to guarantee the conservation of biodiversity (Aide et al., 2000; Holl & Aide, 2011). In this context, ecological restoration has emerged as an attractive alternative to mitigate the negative impacts of human activities on natural ecosystems (Benayas et al., 2009; Chazdon, 2008; Török et al., 2012). However, numerous obstacles remain in the way of restoration ecology (Aide et al., 2000; Florentine & Westbrooke, 2004).

In regions of inappropriate land management, cattle grazing may be considered one of the most harmful activities for forest ecosystems (Ferretti & Britez, 2006), resulting in soil destruction and the loss of important ecological interactions (Holl, 1999). The establishment of pastures necessitates dramatic changes in the environment, including the removal of vegetation cover and tree stumps, repeated burning, the introduction of exotic grasses, and the depletion of the seed bank (Florentine & Westbrooke, 2004). Moreover, the replacement of natural vegetation by pastures also promotes physical and chemical alterations in the soil, such as the loss of edaphic structure and porosity, a reduction in organic matter and the loss of fertility, which all directly affect the establishment and development of plant species associated with succession processes (Guariguata & Ostertag, 2001; Rasiah et al., 2004). Thus, the evaluation of the causes and effects of recruitment limitation in abandoned grasslands is an important step towards the restoration of tropical forests.

Soil characteristics potentially affect the success of forest restoration because plant growth is directly related to the availability of soil nutrients and water, as well as soil porosity (Bassett et al., 2005; Canillas & Salokhe, 2002; Chapin et al., 1986; Lambers et al., 2008). In addition, the presence of grasses has been shown to be a significant barrier preventing the restoration of abandoned pastures (Ferguson et al., 2003; Holl, 1999; Hooper et al., 2002; Hooper et al., 2005; Sampaio et al., 2007). Considering that grass species differ in their growth rates and competitive abilities, it is possible that pastures planted with different grass species differ in their capacity to limit the growth of native trees, thereby affecting

* Corresponding author. Tel.: +55 41 3361 1686; fax: +55 41 3266 2042.
E-mail address: mmarques@ufpr.br (M.C.M. Marques).
[1] Present address: Fundação Grupo Boticário, Rua Gonçalves Dias, 225, 80240-340 Curitiba, Paraná, Brazil.

1617-1381/$ – see front matter © 2014 Published by Elsevier GmbH.
http://dx.doi.org/10.1016/j.jnc.2014.01.001

forest restoration. Thus, investigating the specific effects of exotic grasses and soil types on the survival and growth of tropical forest plants is an important step to restore areas of abandoned pastures.

In southern Brazil, large areas of the Atlantic Forest have been converted into pastures and abandoned over the past several decades, consequently threatening the biodiversity of this important region (Ferretti & Britez, 2006; Kauano et al., 2012). Despite the observation that many disturbed areas have been able to recover from the grassland abandonment by successional processes (Cheung et al., 2010; Liebsch et al., 2007), other areas still remain as pastures, and restoration efforts in these areas are both necessary (Bruel et al., 2010; Ferretti & Britez, 2006) and relatively efficient (Leitão et al., 2010). In these areas, an increase in the biomass of exotic grasses is associated with a reduction in the diversity of tree species, as well as a reduction in the density and volume of native trees. This process has been termed "stationary succession" (Cheung et al., 2010). We hypothesise that the regeneration process in such areas is limited by a deficiency in soil nutrients and soil compaction, as well as competition from other grass species.

The objective of this study was to evaluate the effects of exotic grasses, soil types and soil management techniques on the performance of seedlings in the abandoned pastures of the Atlantic Forest. We compared the seedling survival and growth rates from two tropical trees (a fast-growing tree, *Inga edulis*, and a slow-growing tree, *Campomanesia xanthocarpa*) in pastures with different grass types (*Urochloa* cf. *humidicola* and *Urochloa arrecta*), soil types (Cambisols and Gleysols), and soil management practices (till and no-till), to identify the most important factors that limit forest regeneration. We tested if seedling survival and growth is higher in tilled Cambisols covered by *Urochloa* cf. *humidicola* (a slower growing grass species as compared to *U. arrecta*) and if the faster-growing tree species (*Inga edulis*) exhibit superior performance.

Methods

Study area

The study was performed in abandoned pastures located in the Rio Cachoeira (25°19′15″ S and 48°42′24″ W) and Morro da Mina (25°21′16″ S and 48°46′17″ W) reserves, near Antonina, in the northern coastal region of Parana State, Brazil. According to the Köppen's classification system, the climate in the region is mesothermic humid subtropical (Cfa), with an annual average temperature of 21.4 °C, and an annual rainfall of 2778 mm, without a dry season and with infrequent frosts (Ferretti & Britez, 2006). The main soil types present in the reserves are Argisols, Gleysols, Cambisols, and Neosols (Ferretti & Britez, 2006).

Historically, the reserves were covered by Atlantic Rain Forest, one of the most diverse biomes in the world (Myers et al., 2000). This forest is characterised by high tree density, and the wet climate (caused by ocean humid influence) provides an evergreen physiognomy for the vegetation. The reserves' lands were used for buffalo ranching for approximately 20 years, which required the deforestation of large tracts of forests to establish pastures. Despite being a low impact livestock, this practice resulted in the partial destruction of the original landscape and created a mosaic of vegetation types at various stages of succession (Kauano et al., 2012).

Tree species

We selected two tree species native to the regions' secondary forests, with one species exhibiting slow growth and the other species exhibiting fast growth. Whereas experiments using all species of the region and the three factors of interest (grass species, soil type, tilling) are virtually impossible, we restricted our experiment to two contrasting species that can represent the regular pattern of each ecological group (fast- and slow-growing) in restoration areas. *Campomanesia xanthocarpa* O. Berg. (Myrtaceae) is a slow-growing tree species, is categorised as a deciduous and early secondary species, and is abundant in humid tracts both in high-altitude and coastal forests, although it may be found in nearly all the forest types in Brazil (Lorenzi, 2002). *Inga edulis* Mart. (Fabaceae) is a fast-growing tree species common to seasonal flooded soils, is classified as a semideciduous pioneer species and is found in the Amazon region, as well as across most of the Brazilian coastal plains (Lorenzi, 2002).

Experimental design

The 12-month study was initiated in October 2011 and was performed at 12 different sites (three in the Morro da Mina reserve and nine in the Rio Cachoeira reserve), which were located in the plains of the reserves (∼200 m in elevation). Whereas long term studies provide insights about seedling growth and forest structure in restoration areas, the first 12 months are crucial for seedling survival, because the first unfavourable season can drastically reduce the seedling establishment success and restoration efficiency (Bruel et al., 2010; Zamith & Scarano, 2006). Two soil types were chosen (Gleysol and Cambisol), as well as two different pasture cover types (*Urochloa* cf. *humidicola* and *Urochloa arrecta*), resulting in a total of four unique soil conditions: (1) Cambisol with *Urochloa arrecta*; (2) Cambisol with *Urochloa* cf. *humidicola*; (3) Gleysol with *Urochloa arrecta*; and, (4) Gleysol with *Urochloa* cf. *humidicola*. Three replicates of each condition were used in the study.

In each of the 12 study sites, two contiguous 40 m^2 plots were delineated, resulting in a total of 24 plots. All plots were mown before planting to establish a common standard. Within each pair of adjacent plots, the soil of one was tilled using a rotating till blade attached to a tractor, while the other plot was left untilled (total of 12 plots of 40 m^2 tilled and 12 plots of 40 m^2 untilled). The tilled and untilled sites were planted immediately after the soil preparation and no grass or weed has grown.

An auger was used to manually dig the holes in the soil, and seedlings of either the fast-growing or slow-growing tree species were planted in the holes. Ten *Inga edulis* seedlings and 10 *Campomanesia xanthocarpa* seedlings were planted using a 2 m × 2 m grid spacing, for a total of 20 seedlings per plot and a total of 480 seedlings in the 24 plots.

The seedlings used in the study were cultivated at a local nursery in black 12 cm × 20 cm polyethylene bags, using soil collected from the region and transplanted to the experiment site. Seedlings were approximately 10 months in age and with an average initial height of 16.95 ± 3.88 cm at the beginning of the experiment. Fertiliser was not used in any of the treatments, and the plot-monitoring process involved hand-weeding the plantings every two months.

After the planting, the seedlings' height and basal diameter were individually measured at the beginning and after 12 months of the experiment. In each plot, the soil's resistance to penetration was measured using a penetrometer (for a total of 10 measurements per plot) to test the difference between the tilled and untilled soils. The results of the penetrometer measurements indicated that the untilled parcels generally exhibited a greater resistance to penetration than the tilled parcels (*t*-test, almost all $P < 0.05$), for Cambisol with *U.* cf *humidicola* (average ± SD: untilled: 72.67 ± 6.04; tilled: 48 ± 4.24 kg/cm^2), Cambisol with *U. arrecta* (untilled: 53.00 ± 3.19; tilled: 32.67 ± 1.06 kg/cm^2), and Gleysol with *U.* cf *humidicola* (untilled: 46.33 ± 3.57; tilled: 31.33 ± 1.96 kg/cm^2). One exception was found in the Gleysol plots with *U. arrecta*, in which the resistance of the untilled (33.33 ± 1.61 kg/cm^2) and tilled soil samples (31.33 ± 2.61 kg/cm^2) did not differ significantly ($t = 0.69$, $P = 0.49$).