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Policy Forums

Where do seedlings for *Restinga* restoration come from and where should they come from?

*Julia Dias de Freitas, Ricardo Bertoncello, Alexandre Adalardo de Oliveira, Adriana Maria Zanforlin Martini**

Laboratory of Tropical Forest Ecology, Department of Ecology, Institute of Biosciences, Universidade de São Paulo, São Paulo, SP, Brazil

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ABSTRACT

In a study specifically designed to quantify the production of seedlings grown from seeds collected in Restinga, we found only six from 122 surveyed nurseries in São Paulo state producing local seedlings. Total number of commercially produced seedlings was relatively low. Thus, we compared it with the number of legally committed seedlings to restoration projects in seaside towns in São Paulo state. We found local seedling production representing only one third (32%) of legally committed seedlings. Given this discrepancy between production and demand, we presumed that most of seedlings used in restoration projects in seaside towns has come from other regions. In view of this, we discuss some aspects of the debate about introduction of exogenous seedlings in restoration projects, highlighting the recent literature recommendations for singular ecosystems, such as coastal plain vegetation. We highlighted some potential negative effects on the long-term ecological restoration success and presented some alternative policy actions in order to encourage local seedling production and to register seedling provenance.

Seedling provenance is always controversial when considering ecological restoration projects involving the active planting of seedlings (Lesica and Allendorf, 1999; Mckay et al., 2005; Jones, 2013; Bozzano et al., 2014). However, even in the most studied regions, such as temperate forests, there is a lack of more robust data for supporting discussion on local adaptation (Leimu and Fischer, 2008). At highly diverse tropical regions, studies aimed at guiding decisions related to ecological restoration are scarce (Brancalion et al., 2014). Nevertheless, it is possible to recognize specific local and regional contexts in which the use of local genotypes is recommended (Jones, 2013).

In extremely degraded ecosystems there are few mother trees and genetic flow is reduced. Thus, the use of non-local genotypes (allochthonous) is not only admissible, but even recommended (Rogers and Montalvo, 2004; Jones, 2013).

* *Corresponding author.*
E-mail address: amzmartini@gmail.com (A.M. Martini).
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However, vegetation remnants in well-conserved regions constitute an efficient propagule source, and researchers, either through theoretical reasoning (Mckay et al., 2005) or following the precautionary principle (Belnap, 1995), advocate the use of local genotypes. This would be more important for sites under singular environmental conditions (Jones, 2013), in which some organisms exhibit local adaptations that are important for long-term population maintenance.

In the Brazilian Atlantic Forest domain, the coastal plain vegetation, locally known as "Restinga", is established under unique environmental conditions of nutrient-poor and sandy soils, and the permanent influence of salinity (Araújo, 1984; Scarano, 2009). Although assisted natural regeneration is a low-cost restoration method and highly recommended for many ecosystems, the inefficient water retention of sandy soils imposes a strong barrier to the seed germination and impede vegetation establishment. Thus, active seedling planting methods have been efficient and recommended (Zamith and Scarano, 2006). However, according to a survey of 122 nurseries located at seaside towns of São Paulo State, Brazil (http://labtrop.ib.usp.br/doku.php?id=projetos:restinga:restsul:restaura:start#projetos_desenvolvidos), only six of these (Fig. S1) produce seedlings developed from seeds whose mother trees were located in Restinga areas (hereafter "Restinga seedlings"). In 2010, those nurseries produced about 67,000 Restinga seedlings of 55 species. However, only 37,000 were available for commercialization, since the remainder was exclusively produced for scientific research. The yearly average number of commercialized seedlings indicated by the five commercial nurseries is nearly 32,000.

In order to meet the seedling demand of ecological restoration projects in coastal plains, data were acquired from the government environmental agencies, CETESB and CFA, responsible for monitoring and controlling restoration projects in São Paulo State. All restoration projects registered from 2010 to 2012 for all São Paulo seaside towns were inventoried. The total number of seedlings committed to restoration planting, as well as the yearly averages, was calculated, thereby revealing an annual planting commitment of approximately 100,600 seedlings. Hence, seedling legal demand was nearly three times greater than the production of Restinga seedlings. However, the number of committed seedlings may have been overestimated since seaside towns have part of their territories occupied by Dense Ombrophilous Forest established on mountainous terrains (details in Table S1).

Based on these results, part of the seedlings used in Restinga restoration projects could be presumed to come from another region. As several species occurring in the Restinga originate from adjacent Tropical Ombrophilous Forests (Marques et al., 2011), and others are widely distributed, including in areas of Tropical Seasonal Forests, additional seedlings probably came from these inland regions. A plausible explanation for the scanty seedling production by seaside nurseries might be the lower seed production of mother trees in Restinga, when compared to other regions, as observed by Brancalion et al. (2012) for palm heart (*Euterpe edulis*). On the other hand, the acquisition of seedlings from inland nurseries may have been facilitated by their potentially lower costs, made possible by the large-scale production of seedlings.

The consequences of using non-local seedlings for restoring Restinga vegetation could be negative for local plant populations, since restrictive abiotic conditions are capable of selectively enhancing traits that provide higher fitness in local populations (Hufford and Mazer, 2003; Mckay et al., 2005; Hereford, 2009). Local adaptation at very small spatial scale has been described in plant populations, with average performances increasing about 45% in original habitat when compared to other habitats (Hereford, 2009; Leimu and Fischer, 2008). Thus, in spite of the relative closeness to hillside ombrophilous forest remnants, and the occurrence of species with high phenotypic plasticity (*Guapira opposita*, *Calophyllum brasiliensis*) in coastal plain areas, soil characteristics and salinity can impose very restrictive conditions, thereby resulting in locally adapted populations of some species. Likewise, local adaptation at small temporal scale has been observed for plants in mine contaminated soils, suggesting rapid selection to soil conditions (Jain and Bradshaw, 1966). Thus, even with the relatively recent (5000 to 10,000 years) establishment of Restinga vegetation, and the low endemism rates of tree species in the coastal plain areas (Marques et al., 2015), some species could have locally adapted populations. Unfortunately, there is no scientific evidence on the proportion of phenotypically plastic species or locally adapted populations in the Restinga flora, as a whole.

Among the worst scenarios, gene transference from exogenous genotypes could lead to lower fitness in subsequent generations, and consequently, to outbreeding depression (Keller et al., 2000; Crémieux et al., 2010). In an ecological community context, decreasing fitness in local populations could give rise to long-term changes in species biomass or abundance (Hufford and Mazer, 2003; Mckay et al., 2005). These changes, besides affecting local biotic interaction networks, could also strongly alter plant community structure and related ecosystem processes. Under these circumstances, the introduction of exogenous seedlings could lead to the long-term failure of Restinga ecological restoration projects.

Considering the absence of a comprehensive study of evolutionary divergences in the Restinga flora, certain non-restrictive, precautionary public policies could be recommended. The use of local, or established on similar environmental conditions, mother trees as seed sources for Restinga restoration projects should be encouraged. A plausible alternative for ecosystems under restrictive conditions would be to establish a legal mechanism providing sufficient time, possibly 18 months, for established or provisional nurseries to produce local seedlings prior to planting. This would allow for better planning and lower investment risks for established local nurseries that are not currently producing Restinga seedlings, as well as advantages for the local economy.

Furthermore, it would be interesting to initiate discussion on the establishment of seed collection zones (St. Clair, 2014). In the first instance, these should be located in nearby regions. However, due to the difficulties in finding mother trees in the immediate neighborhood, seeds should be collected in other compatible Restinga areas, with the same species and under similar environmental conditions, even though geographically distant. This recommendation is based on the "habitat matching" principle, in which the optimal genotype would be the most related to specific habitat conditions (Byars et al., 2007; Broadhurst and Boshier, 2014; St. Clair, 2014). The main difficulty would be to guarantee seed provenance (Mijnsbrugge, 2014).

In spite of the data presented here being restricted to São Paulo State, this situation seems not to be confined unique to this region. Except for Rio de Janeiro State (Zamith and Scarano, 2004), Restinga seedling production is primarily restricted to scientific research projects and basic information about Restinga vegetation is scarce. Thus, seedlings for restoration projects are probably being selected without specific criteria in most coastal areas. It is noteworthy that the same recommendations for Restinga also apply to other ecosystems established under singular environmental conditions, such as "*campos rupestres*" ("rocky fields"), ironstone outcrops, inselbergs, white-sand vegetation (campinaranas, kerangas, heath forests), and swampy forests, both inside and outside Brazil.

Even though the outcome of the introduction of exogenous seedlings is uncertain, and if the "precautionary" and the "habitat matching" principles are to be accepted, the use of seedlings from the same system should be encouraged, or, at least, seedling provenance should be officially registered. In the face of restoration activities established by current federal legislation (Native Vegetation Protection Law – 2012), and proposed in the PLANAVEG (National Plan for Native Vegetation Recovery – available at http://www.mma.gov.br), presumedly there will be an increase in seedling demand in the near future (Brancalion et al., 2016). Public policies aimed at encouraging local seedling production, and the registration of seedling sources should be incorporated into future government action.

Conflicts of interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ncon.2016.09.002.

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