BRAZIL NUT (*BERTHOLLETIA EXCELSA* BONP.) REGENERATION GROWTH IN A FALLOW AREA IN RELATION TO SOIL FERTILITY AND SECONDARY FOREST SERAL STAGE

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RESUMO

A castanheira da Amazônia (*Bertholletia excelsa*, Bonpl.), pertencente à família Lecythidaceae, é uma espécie que habita ambientes de terra firme de vários países amazônicos. A regeneração natural, assim como o crescimento, de castanheiras em áreas de capoeiras pode ser muito superior à regeneração em castanhais dentro da floresta. Entender como os fatores ambientais nas capoeiras estão relacionados com a dinâmica das regenerações de castanheiras é uma questão importante para orientar o manejo e aproveitamento dessas regenerações. Assim, o objetivo deste trabalho foi estudar a regeneração natural de castanheiras sob vegetação secundária, verificando quais fatores da fertilidade do solo podem ser associados ao seu crescimento inicial e se esse desenvolvimento é diferenciado em função da idade da capoeira. Cada regeneração de castanheira foi georreferenciada e o tipo de vegetação (capoeira alta ou capoeira baixa) na qual estava inserida foi anotado. Em cada regeneração foi realizada anualmente, a medida de altura e de diâmetro na base do solo, o que permitiu calcular as taxas de incremento. Para amostrar o solo foram coletadas 17 amostras próximas a regenerações distribuídas em diferentes partes da área. Para os cálculos de incremento foram utilizados dados de 2009 e 2010, quando foram coletadas as amostras. Ao final do monitoramento foi contabilizado um total de 166 regenerações de castanheiras. A análise de regressão múltipla do incremento em altura em função dos macronutrientes e acidez do solo foi altamente significativa ($F= 11,812$; $p= 0,00068$), porém somente o potássio (K) apresentou valores significativos ($F= 26,41343$; $p= 0,00015$). As regenerações de castanheiras em ambientes antropizados apresentam taxas elevadas de crescimento, que são dependentes da idade da capoeira. O principal atributo da fertilidade do solo associado ao desenvolvimento das regenerações de castanheiras foi o teor de potássio no solo.

ABSTRACT

The brazil nut tree (*Bertholletia excelsa* Bonpl.), is a *Lecythidaceae* species with a broad distribution throughout the Amazonian upland Forest. Natural regeneration and tree growth is higher in secondary forests, fallows, and disturbed areas than under the closed canopy of mature forests. The understanding of environmental factors affecting the population dynamic in fallows is important to guide management efforts and to use this natural regeneration potential for the benefit of the species' conservation. Thus, the study focused on the natural regeneration and growth rate of brazil nut trees spontaneously colonizing secondary forests after agricultural disturbance. Data on growth rate was associated with soil fertility for two seral stages of the secondary forest. Each brazil nut regeneration found in both young and older fallow was measured in height and diameter at soil height in 2009 and 2010. Soil samples were taken in 17 locations close to regeneration clumps. A total of 166 brazil nut seedlings and saplings were measured. A multiple regression analysis detected a significant relation between height increase and soil macronutrients content ($F = 11.812$; $p < 0.001$). However only potassium showed a significant correspondence with growth ($F = 26.413$; $p < 0.001$) for the individual correlation tests. Growth rates of brazil nut regeneration depends of the age of the secondary forest colonizing the fallows. For the studied area, the main soil nutrient related to variation of seedlings and saplings growth was potassium.

INTRODUCTION

The brazil nut tree is one the most useful Amazonian species, and considered a symbol for sustainable development of the region (Clay 1997). The nuts feed the native fauna capable to crack- or gnaw-open the fruits, like the specialist agoutis (*dasyprocta*), and eventual acouchis (*Myoprocta*), macaws (*Ara*), and even monkeys (*Cebus*). The nuts are also prized by humans, supplying a protein-rich food resource and a valuable commodity for the forest dwellers. Such economical importance gave the species a head start among the protected species, with immunity against timber industry granted by the Brazilian law. Conflicts between extractive population and cattle ranchers, farmers and loggers resulted in the institution and creation of several Extractive Reserves throughout the species biogeographical range since 1990.

The possibility to manage the abundance of regeneration found in anthropically disturbed forests to promote the renewal and expansion of the brazil nut stands (Paiva et al. 2011), reinforces the justification for studying fallows, especially for understanding the species' growth under these environments. The management of the spontaneous brazil nut regeneration minimizes costs associated with nursery keeping, transplanting and initial growth care. The brazil nut shows a long dormancy period, and the seedling may still be predated by rodents or ants even several months after emergence.

The higher regeneration rate in anthropically disturbed areas may be explained by favorable biotic and abiotic conditions for the plants development. Besides that, the agouti, as the natural seed disperser, also show a preference for dense and entangled understory areas (Silvius and Fragoso), like those commonly find in early stages of fallow succession.

The brazil nut is a heliophyta with regeneration associated to canopy gaps (Mori and Prance, 1990). The species shows a significant growth in height and diameter when planted in open areas (Soares et al. 2004). The brazil nut is frequently found in low fertility soils, with good physical structure, well drained, and medium texture (Locatelli et al., 2003). Despite the number of studies demonstrating the association between abiotic variables and the development of brazil nut trees, researches focusing the relation between soil nutrient variables with the species growth rate are scarce.

The objective was to study the natural regeneration of brazil nut trees spontaneously established in secondary forests of contrasting seral stage, to access which soil fertility factors could explain the differences in the initial growth of seedlings and saplings.

MATERIAL AND METHODS

The study was realized in the property of Mr. Tomé de Sousa Belo, in the Carvão community association, Southeast of the Amapá State (0°35'06.8"S; 52°14'11.2"W), Brazilian Amazon. The region has vegetation coverage in transition between upland forest and lowland forests under influence of seasonal flooded regime and is not part of the original brazil nut trees' distribution. The adult trees found in the area were introduced in the year of 1981, as planted seeds. According to Mr. Belo the trees started bearing fruits in 1990. Since then, brazil nuts became part of not just his family diet, but also for the agoutis living in the area, as became clear by the increasing number of seedlings, which rely entirely on the scatter hoarding habit of the agoutis to escape their armored pyxidium.

This study makes use of the same area previously sampled by Paiva and Guedes (2008). Also studying the regeneration of the brazil nut trees, those authors located the reproductive adult trees and all the seedlings and saplings found on a radius of 100 m from the center of the planted cluster. In the occasion, the regeneration individuals were measured in height and diameter at soil height, and labeled. Following the original data, the same measures were repeated in 2009 and 2010, to allow the understanding of the regenerating population dynamic and growth rates.

The seedlings and saplings were found in two types of fallow. A 30 years old one (2011), dating of the time of the last shifting cultivation cycle in the area, when the brazil nut trees were first introduced. And a younger fallow area, from the same crop, but which was also kept as an orchard for some years, and currently shows a much younger seral stage.

Soil samples were taken near 17 individuals. For the sampling, the area was divided in four parts, in an attempt to include the variation in fallow age and relief. Soil cores were obtained with a metal probe with a diameter of 2 cm, in the 0-10 cm depth. The soil surface around each sampled individual was divided in quarters, and for each of the quarters, four soil samples were taken, in a total of 16 sub-samples that were combined and homogenized to compose a single sample. Soil analyses were carried out in Embrapa Amapá, following the methods described by Nogueira and Souza (2005).

RESULTS AND DISCUSSION

By the end of the monitoring period, a total of 166 brazil nut seedlings and saplings were found, already showing an intensive natural regeneration, only 30 years after the species were introduced in the area. Paiva et al (2011), working in the Rio Cajari Extractive Reserve, also in the South of the Amapá State, equally found a high density of brazil nut regeneration in shifting cultivation fallows. The authors found an average of 33 trees.ha^{-1}, with a maximum of 103 trees.ha^{-1}.

According to Baider (2000), an explanation to the high index of appearance of this species is due to the fact that the area is a fallow, were the sun light shines directly on the soil. The author affirm that this is a determining factor for breaking dormancy, germination and for the development of the young individuals

Comparing the density of juveniles between the fallow areas and the mature brazil nut stands, it is clear that the regeneration density in fallow is very high. Serrano (2005) states that the luminosity under the forest canopy, is insufficient for the establishment of new individuals of the species. This author found an average density of 2.07 ind.ha^{-1} inside the forest. Beyond the abiotic factors that possibly contributed for the high density of individuals in this fallow area, another determining factor is the role of the agoutis, which carry and bury the seeds.

In the area of the present study it was observed that, in most of the cases, the brazil nut regeneration occur in clumps. According to Paiva and Guedes (2008), these clumps may have originated from a single dispersion event, or even from a single fruit.

Possibly, one of the reasons for this seedlings and saplings to be found so close together may result from an agouti's strategy for increasing the chances of finding previously buried seeds, scattering them in a relative proximity to

each other. In any case the animal may not find all the buried seeds, contributing to the dispersion and regeneration of the species.
The monitoring kept up with 131 brazil nut regeneration. These plants showed a mean annual growth of 42.1 cm, varying from 0 to 370 cm. The average soil height diameter growth was 5.7 mm per year, varying from 0 to 25.2 mm. According to Salomão et al. (2006), diameter growth superior to 2 cm per year qualifies the brazil nut as a species with potential to colonize degraded areas.
In relation to the type of fallow, the average annual increase was higher for the seedlings and saplings growing in the younger fallow (Figure 1). The difference between the two types of fallow was highly significant for the increase in height ($T = -3.22$; $p = 0.002$). For the increase in diameter at soil height, the difference was significant up to a level of 8% of error probability ($t = -1.74$; $p = 0.082$). This demonstrates that the age of the fallow is a limiting factor for the growth of brazil nut regeneration. Paiva and Guedes (2008) also found similar results, with variations in size of the plants established on both fallows. These authors propose that in younger fallows there are better environmental conditions for the development of the plants within. And, for the older fallow area, the growth rate is less intensive, resembling the understory of mature forest. According to Baider (2000), for the brazil nut regeneration, height increases are more important than diameter increases, as a strategy for reaching the canopy height as soon as possible, and guarantee its establishment.

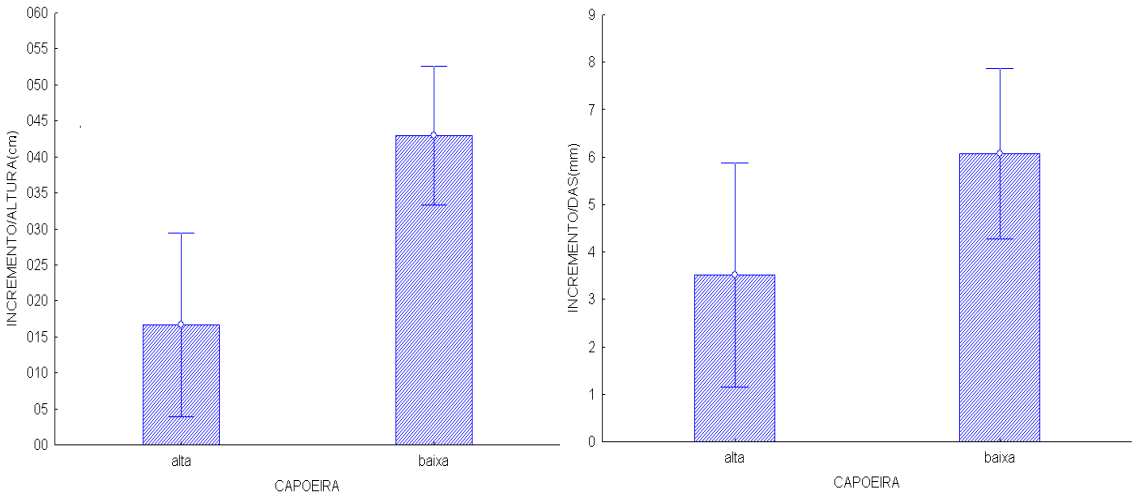

Figure 1: Average annual growth and confidence intervals at 95% certainty, for the values of height and diameter at soil height for two ages of secondary forest in south Amapá (n=131).

A multiple regression analysis of the height increase in function of pH, organic matter, phosphorus, potassium, calcium + magnesium, aluminum + hydrogen, sum of bases, bases saturation, and aluminum saturation was significant ($F = 11{,}812$; $p > 0.001$), however, only the potassium showed significant values ($F = 26.41$; $p < 0.001$). A linear regression between the height increase and potassium showed a coefficient of correlation $r = -0.8$ (Figure 2).

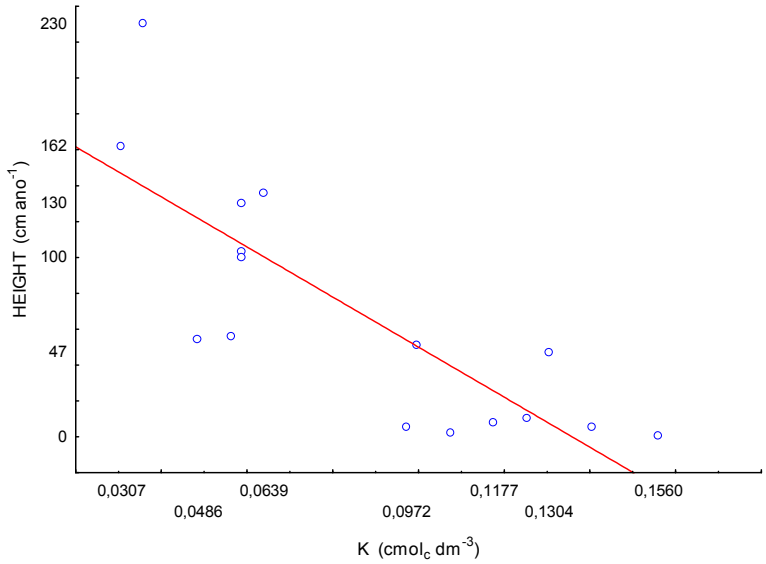

Figure 2: Linear regression of the height growth of brazil nut regeneration as a function of the potassium concentration in the soil from 0-10 cm depth.

The negative relation shows that height growth decreases with increasing levels of potassium in the soil. Probably, due to the high demand for this nutrient, the available supply of potassium in the soil closer to these plants was absorbed, resulting in better growth rate were the nutrient appears less concentrated. According to Pavinato et al. (2009), the intensive growth of the aboveground parts of some plants may be explained by the increased uptake of some soil nutrients, and consequently its decrease in the soil.

CONCLUSIONS

- Brazil nut regenerations under secondary forest show high growth rates, which depends of the age of the secondary forest.
- Soil potassium may be associated with the growth of brazil nut regeneration under secondary forest.

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