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Initial behavior of arbor species in different locations of the terrain in neutralization plants

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ABSTRACT: The rapidly increasing demand for GHG neutralization projects has inspired certain tree species to be planted in degraded regions. This popular option combines the great carbon sequestration potential with the advantages of the recomposition of the vegetation of these regions. From this perspective, information concerning the adaptability, behavior and initial development of these tree species under various edaphoclimatic types of conditions, and as estimated in the current study, the effect of relief locations on their growth, are very essential. This study was performed on a mixed plantation to neutralize the GHG emissions produced in the UFV due to an annual event. The terrain was stratified into three levels based on specific parameters such as relief and survival rate, mean monthly height increase (IMMH) and mean monthly diameter increase (IMMD), 342 seedlings, of 18 types of 17-month-old tree species. The IMMH and IMMD variables were submitted to ANOVA and found significant after being subjected to F-Test. The findings emphasize the significance of studies of this nature as they facilitate the identification of species behavior and enable the selection of trees most suitable for the neutralization projects, based on their carbon-storing potential.

Keywords: adaptability, gradient, toposequence.

Comportamento inicial de espécies arbóreas em diferentes posições do terreno em plantio de neutralização

RESUMO: Motivado pela crescente demanda de projetos de neutralização de GEE, o plantio de espécies arbóreas em áreas degradadas tornou-se uma alternativa comumente utilizada, unindo o alto potencial de fixação de carbono e os benefícios gerados pela recomposição vegetal dessas áreas. Nesse contexto, é de grande interesse o conhecimento da adaptabilidade, comportamento e desenvolvimento inicial dessas espécies em diferentes condições edafoclimáticas, e como avaliado no presente trabalho, a influência das posições do relevo no desempenho dos indivíduos arbóreos. O estudo foi conduzido em plantio misto com intuito de neutralizar emissões de GEE gerados em um evento realizado anualmente na UFV. O terreno foi estratificado em três posições de acordo com o relevo e foram avaliadas, quanto a sobrevivência, Incremento Mensal Médio em Altura (IMMH) e Incremento Mensal Médio em Diâmetro (IMMD), 342 mudas, de 18 espécies, aos 17 meses de idade. As variáveis IMMH e IMMD foram submetidas a ANOVA e de acordo com o Teste F apresentaram-se significativas. Este resultado demonstra a importância de estudos como este de modo a identificar o comportamento das espécies e permitir a seleção das mais adequadas para projetos de neutralização de acordo com seu potencial de estocar carbono.

Palavras-chave: adaptabilidade, gradiente, topossequência.

1. INTRODUCTION

Greenhouse Gas Emissions inventory, a reliable resource, reveals emission profiles and facilitates the establishment of mitigation targets (GHG PROTOCOL BRASIL, 2016). Thus, institutions and organizations can control the GHG production and minimize their negative influences on the environment (ALVES et al., 2015).

There is a rapidly growing demand for emission inventories and, therefore, GHG neutralization projects have increasingly sprung up over the last few years. One commonly employed alternative in the neutralization projects is planting specific tree species, selected for their high carbon-fixing potential.

Besides neutralizing the GHG emissions, these projects also offer other environmental advantages. Hassan (2009) stated that some institutions focus their neutralization projects on recovering deforested regions, which promote water production and quality, maintain biodiversity and forest connectivity as well as restore Permanent Preservation Areas (APPs), including specific Socio-environmental criteria. This study also

emphasizes the alternative of incorporating Legal Reserves through neutralization projects.

From this perspective, the Atlantic Forest was selected to implement the GHG neutralization projects, as it enables the recomposition of one of the world's most fragile biomes (VARJABEDIAN, 2010). Some rural landlords do not comply with the current environmental legislation.

However, to ensure that plantations flourish, the various factors involved and their direct or indirect effects on the growth of the forest species must be understood. These include species inherent characteristics, edaphoclimatic conditions and management practices (COTTA, 2008). Therefore, the adaptation potential of the species to each of these variables must be identified, in order to gain information to wisely select the tree species for good composition of forest neutralization and successful recovery projects.

From this perspective, relief is a very significant factor that influences soil properties, as it controls water flow and accumulation throughout the landscape via gravity (FLORINSKY and KURYAKOVA, 1996). Silva (2007) proposed that land relief affects the spatial distribution of the trees in the Atlantic Forest; however, studies relating to this influence in this biome are very limited. Besides, the slope of the landscape, in conjunction with other factors, results in a variety of environmental situations, like soil moisture gradients between the base and top, weakening soil particle transportation along the land profile and varying times of solar radiation exposure (GANDOLFI, 2000)

Gonzaga et al., (2014) had reported this influence earlier in his study on a mixed plantation, with the goal of recovering a gravel region in the Biribiri State Park, in Diamantina, Minas Gerais. They confirmed that the uneven terrain affected the seedling growth of the forest species.

However, incipient studies are available concerning the adaptation and development of the forest species (NASCIMENTO et al., 2012), particularly in the landscape. Therefore, the present study aimed at evaluating the adaptability and initial growth of 18 tree species in different locations of the land in the Mata Atlantic biome, in a GHG neutralization planting project and degraded region recovery effort.

2. MATERIAL AND METHODS

2.1. Area of study

This study was performed in the Open Space of Events of the Federal University of Viçosa (UFV), in Viçosa, Minas Gerais, located at the geographical coordinates of 20º45'35 "S and 42º52'29"O (Figure 1). Tree planting was done under the Zero Carbon Program of the UFV aiming at neutralizing the GHG emissions from the events conducted by the institution.

The climate of Viçosa based on the Köppen system was Cwa, indicating a subtropical type, with dry winters and hot and rainy summers (ROLIM et al., 2007). From the time of planting till the last data was collected, the average temperature was 21.39ºC and accumulated rainfall was 1718.2 mm (UFV, 2016).

Planting was done in December 2014, in 0.15 ha, using a selected combination of native forest species from Brazil (Fig. 1). In all, 342 seedlings from 18 species were planted, with 2 m x 2 m spacing. The terrain was stratified into three levels: an upper third (UT), a middle third (MT) and lower third

Figure 1. Study area.
Figura 1. Àrea de estudo.

commencing the descent (LTD). Each terrain level assessed included 6 experimental lines.

Earlier, as the plantation area had been covered with brachiaria (*Urochloa decumbens* (Stapf) R. D. Webster), mowing was done to lessen the competition.

The pit dimensions were standardized with the motorcoveadora to 0.30 m x 0.30 m x 0.30 m. Next, basic fertilization was done by adding 300 g of Simple Superphosphate (18% P2O5) to each well. Cover fertilization was performed after 30 days, with 100 g of NPK in the formulation of 20-5-20 per plant. A circular distribution format was followed around the molt, in the projection of the crown of the same.

The area was periodically monitored, to control the cutting ants, crowning of the seedlings and forest competition.

2.2. Evaluation of the parameters

The method of Oliveira et al., (2015) was followed for the analysis of survival (Equation 1) and growth of each species, according to the equations mentioned below.

$$S_j = \left(\frac{N_{fj}}{N_{0j}}\right) \times 100 \qquad (1)$$

where Sj = survival of the *j*th species, in %; Nfj = number of surviving individuals of the *j*th species; N0j = initial number of the *j*th species planted.

Growth was evaluated utilizing the Mean Monthly Increase (IMM), in diameter (Equation 2) and height (Equation 3).

$$IMM_{Dj} = \frac{1}{I \times N_j} \times \sum_{i=1}^{n} \left(D_{fij} - D_{0ij}\right) \qquad (2)$$

where IMMDj = mean monthly increase in diameter of the *j*th species, in mm.m.-1; I = planting age, in months; Nj = number of individuals of the *j*th species; DFij = final diameter of the *i*th individual of the *j*th species, in mm; D0ij = initial diameter of the *i*th individual of the *j*th species, in mm.

$$IMM_{Hj} = \frac{1}{I \times N_j} \times \sum_{i=1}^{n} \left(H_{fij} - H_{0ij}\right) \qquad (3)$$

where IMMHj = mean monthly height increase of the *j*th species, in cm.mês-1; I = planting age, in months; Nj = number of individuals of the *j*th species; HFij = final height of the *i*th

individual of the *j*th species, in cm; H0*ij* = initial height of the *i*th individual of the *j*th species, in cm.

The trees were evaluated at 17 months of age. Using a graduated measuring tape the height was measured in centimeters, while diameter was recorded at the ground level in millimeters with a precision digital caliper.

Variance Analysis (ANOVA) was done to assess the presence of significant differences between the parameters evaluated among the species, as well as in the different locations of the terrain.

3. RESULTS

The planting at 17 months showed an overall survival of 79.2%. At the UT, MT and LTD locations, the survival percentages were 73.1%, 82.4% and 81.5%, respectively (Table 1).

Despite the distinction, variations in the survival in the different locations on the terrain confirmed that the only relation identified was that the F test of the Analysis of Variance (ANOVA) was not significant; this indicates that the survival of the individuals is not a factor dependent on the toposequence under the conditions of the current study (Table 2).

On the contrary, survival was identified as being significantly influenced by species variation. From this angle, *Enterolobium contortisiliquum* and *Peltophorum dubium* were confirmed as showing the highest survival percentage (100%), irrespective of their location on the terrain.

Among the 18 species assessed, 11 were observed to have a higher IMMD in LTD., 4 in UT and 3 in MT, indicating that the species in the lower third and ground below developed much better than those in the other locations (Figure 2).

The species revealing the greatest IMMD occurring in the LTD were *Peltophorum dubium* (4.23 mm.m.-1) and *Chorisia speciosa* (3.87 mm.m.-1).

With respect to the height variable, 10 species were confirmed to have the hightest IMMH in LTD and 8 species in UT (Figure 3). For this parameter, none of the species showed better development in MT. The species showing the highest IMMH occurred in UT and LTD, viz., *Enterolobium contortisiliquum* (15.71 cm.m.-1) and *Peltophorum dubium* (17.57 cm.m.-1).

For the species *Sparattosperma leucanthum*, the IMMH value was negative (-1.43 cm.m.-1), the reason for this fact is the occurrence of stem smashing in this species.

Table 1. Species survival in the different locations on the terrain: Upper third (UT); Middle third (MT); Lower third with the commencement of descent (LTD) and General.
Tabela 1. Sobrevivência das espécies nas diferentes posições do terreno: Terço superior (UT); Terço médio (MT); Terço inferior com início de baixada (LTD) e Geral.

Species	Survival			
	UT	MT	LTD	Geral
Apuleia leiocarpa	83.3	50.0	100.0	78.9
Caesalpinia echinata	50.0	100.0	100.0	84.2
Cassia grandis	50.0	83.3	83.3	73.7
Centrolobium tomentosum	100.0	83.3	100.0	94.7
Chorisia speciosa	50.0	100.0	83.3	78.9
Citharexylum myrianthum	33.3	66.7	83.3	63.2
Dalbergia nigra	50.0	50.0	16.7	36.8
Enterolobium contortisiliquum	100.0	100.0	100.0	100.0
Eugenia uniflora	83.3	100.0	100.0	95.0
Garcinia gardneriana	83.3	100.0	100.0	89.5
Goniorrachis marginata	100.0	100.0	83.3	94.7
Hymenaea courbaril	83.3	66.7	66.7	68.4
Joannesia princeps	50.0	83.3	50.0	63.2
Lecythis pisonis	83.3	100.0	100.0	94.4
Machaerium stipitatum	66.7	100.0	83.3	84.2
Peltophorum dubium	100.0	100.0	100.0	100.0
Piptadenia gonoacantha	83.3	83.3	83.3	84.2
Sparattosperma leucanthum	66.7	16.7	33.3	42.1
Average	73.1	82.4	81.5	79.2

Table 2. ANOVA results.
Tabela 2. Resultados da ANOVA.

Parameter	gl	S		IMMD		IMMH	
		F	p	F	p	F	P
Species	17	3.72	<0.05	8.39	<0.05	6.86	<0.05
Positions	2	1.62^{ns}	0.21	6.22	<0.05	7.89	<0.05

4. DISCUSSION

The overall survival of the planting was as expected for the area as that of the study in question.

The behavior of the species *Enterolobium contortisiliquum* e *Peltophorum dubium* may be due to the rusticity of the plants and the nitrogen fixation capacity of the atmosphere, via the effective symbiotic relationship with *Rhizobia*, which all the species of the Fabaceae family enjoy (AZEVEDO et al., 2007). Greater interest may be thus kindled in utilizing these species in the neutralization plantations.

Enterolobium contortisiliquum, a species with rapid growth, has already found use in the reforestation of degraded regions. Besides, because of the heavy litter deposits, it enables soil regeneration where organic matter is lacking and nutrient cycling is still limited (SUGAI, 2007). The species *Peltophorum dubium* shows identical characteristics exhibiting total survival among all the individual trees. This plant, which is rustic and fast growing, is also being considered to be a part of the mixed reforestation of the degraded regions (PORTELA et al., 2001). Further, the high degree of survival revealed in the current study for this species, concurs with the data from Embrapa, which states that most of the plantations show survival rates above 80% (CARVALHO, 1994).

The growth parameters, after subjection to the F test emphasized that the average monthly diameter (IMMD) and height (IMMH) increase are significantly influenced by the species in question, as well as the location on the terrain. This implies that the individuals grow in different ways based on the location they occupy along the terrain. Marangon (1999) reported evidence supporting this fact, demonstrating that the arboreal vegetation may prefer some points than others in the toposequence.

In the study conducted by Teixeira (2009), assessing the phytosociology and floristic aspects of the arboreal component in toposequenc, there were reported that the species revealed specific characteristics in the relief and showed a preference for different habitats. Silva (2011), explained that variations in the physical and chemical properties of the soil at different locations on the slope directly influence the vegetation growth. Besides, he also highlighted that the Brazilian soils have distinctly marked features of high acidity and low fertility, and when the relief factor is considered, as these involve sloping regions, the bases are even more easily removed.

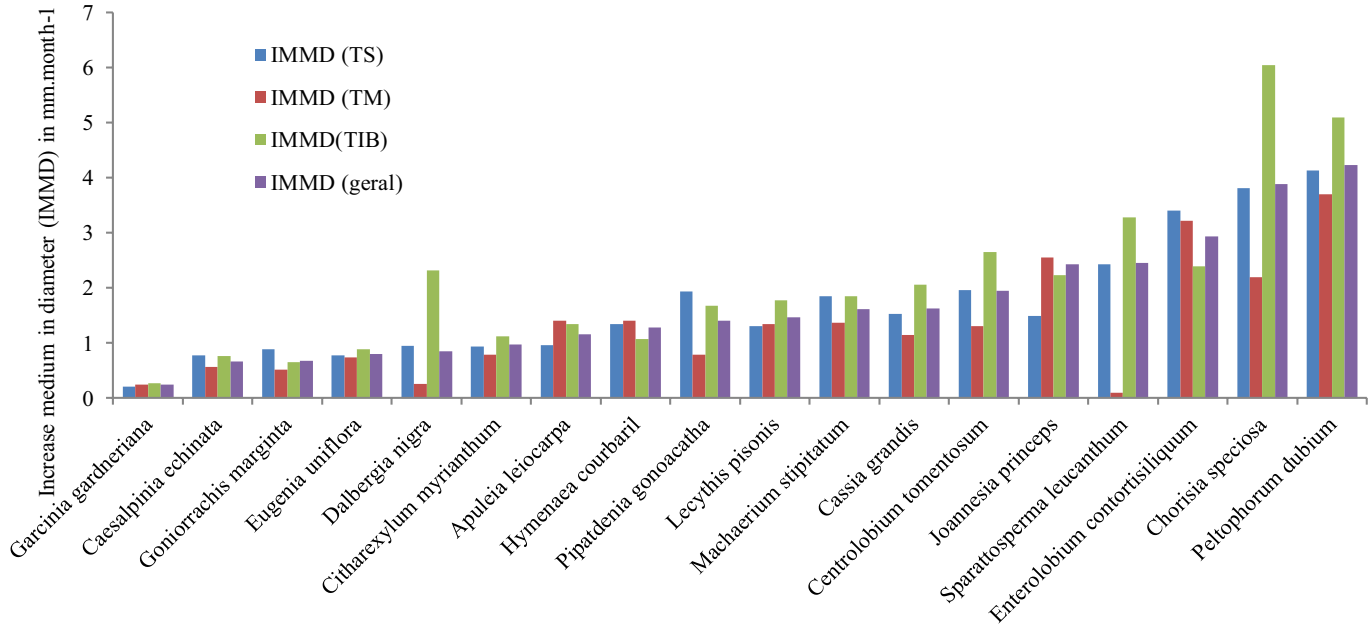

Figure 2. Increase in diameter (IMMD) in mm.month^{-1} of the species in the different locations on the terrain: Upper third (UT); Middle third (MT); Lower third with commencement of descent (LTD) and General.
Figura 2. Incremento em diâmetro (IMMD) em mm.mês^{-1} das espécies nas diferentes posições do terreno: Terço superior (UT); Terço médio (MT); Terço inferior com início de baixada (LTD) e Geral.

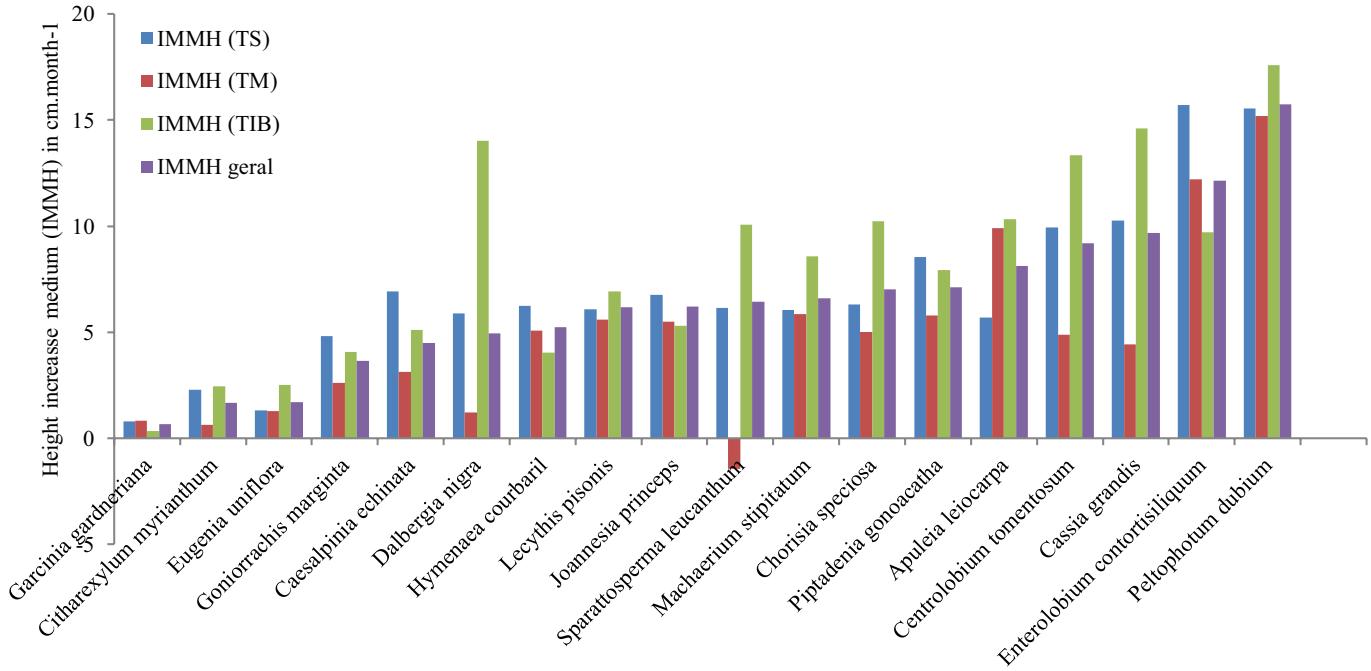

Figure 3. Height increase (IMMH) in cm.mês^{-1} of the species in the different locations of the terrain: Upper third (UT); Middle third (MT); Lower third with commencement of descent (LTD) and General.
Figura 3. Gráfico de Incremento em altura (IMMH) em cm.mês^{-1} das espécies nas diferentes posições do terreno: Terço superior (UT); Terço médio (MT); Terço inferior com início de baixada (LTD) e Geral.

Canellas et al., (2000) in their study expressed another reason with reference to the variations visible in the organic matter content of a toposequence. This directly impacts the physical, chemical and biological processes of the soil and therefore is linked with soil fertility, establishment and behavior of the different species.

From this angle, it was obvious that most species (89%) responded in different ways to the field locations assessed. This fact emphasizes the concept that relief strongly affects the nutrient availability along a toposequence, as confirmed by Balieiro et al. (2008).

The best development of the species in the LTD can be attributed to the climatic processes inherent to soil formation which influence the movement of the nutrients from the higher locations and, subsequently, concentrating them in the lower locations on the terrain (BOCKHEIN, 2005). Further, because of the higher organic matter concentration in the profiles of the locations in the lower third, as well as the greater vertical infiltration of water (SILVA, 2011).

The result obtained for the species *Chorisia speciosa*, which obtained one of the largest IMMD in LTD, concurs with the findings of Lima et al. (2009), which shows as a species

specific feature, the prioritization of diametric growth, which is fundamental for it being established.

Besides the greater survival, the highlight in the IMMH of the *Enterolobium contortisiliquum* and *Peltophorum dubium* species reveal the potential of the species of family Fabaceae. Thus, it is verified that this family should be thoroughly investigated for use in neutralization plantations.

Although the UT represents the smallest survivor index of the experiment, it is possible affirming that at the same relief portion the species do not present less development, while the MT present that characteristic.

5. CONCLUSIONS

The species can exhibit a variety of behaviors, even when planted in the same location. When the variations in the terrain are identified, the management methods can be improved for the carbon neutralization projects, concurring with the recovery of deforested regions.

The gradient of the terrain showed no significant impact on the species survival at 17 months; however, it did affect the species growth and development. The predominant development of most of the tree species in the lowland regions is explained by the higher accumulation rates of the nutrients, organic matter and vertical water infiltration in that part of the terrain.

Enterolobium contortisiliquum and *Peltophorum dubium* showed nil mortality, irrespective of their location on the terrain. Besides, they rank among the species with the highest growth for the variables assessed. This reveals the high potential that they possess to be selected for the heterogeneous plantations of GHG neutralization and recovery of degraded regions.

The Fabaceae family was prominent in terms of the survival index and the IMMH, evidence for the potential of this species to be selected for the composition of mixed GHG neutralization plantations under conditions like those described in this study.

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