Reclamation of degraded areas in Eastern Amazonian: the potential of *Sclerolobium paniculatum* Vogel

by

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Abstract. *Sclerolobium paniculatum* Vogel (taxi-branco) is a legumenous tree native to the Brazilian Amazon region. It occurs in different types of soil and fix atmospheric nitrogen. The mechanical dormancy of the seeds may be overcome by immersing in boiling water and then removing them from the heat until the water cools to room temperature. The seed germination occurs in approximately 30 days. In greenhouse conditions, taxi-branco does not respond to the application of Ca and S. The critical levels in the soil of these two nutrients were 0.37 meq/100 cm^3 and 5.10 mg/cm^3, respectively. The silvicultural performance of taxi-branco may be considered satisfactory when compared to other native tree species of the Amazon. In homogenous plantations, taxi-branco trees produce about eight tons of litter per hectare. Its rapid growth accompanied by a high production of litter and its N fixation qualify this species as potentially suitable for the recuperation of degraded soils by human actions.

Additional Key Words: Amazon region, nutrients, critical levels, legume tree, etc

Introduction

The economic activities developed in the Brazilian Amazonian have caused different levels of degradation. From an environmental point of view, exist effects on biodiversity involving the losses or damages to the animal and/or plant populations, as well as alterations in the critical functions of the natural ecosystems, modifications in the carbon stores, quantities of water transpired and the retention of nutrients. Estimates shows 25 to 34 million hectares of native forest, have already been altered. (INPE, 1990; Skole & Tucker, 1993 and Feanrside, 1993).

The search of environmental conservation practices must be based upon more sustainable production systems, involving biological, social and economic aspects. Restoring the productivity of areas considered altered or degraded, must be the object of continuing research. The use of species more adapted and production systems more efficiently in the humid tropical areas are the key for sustainability.

Reforestation programs in the Brazilian Amazonian are limited to a few regions such of Para and Amapa States. The mainly species used in plantations programs are non-native, e.g. *Pinus caribea*, *Eucalyptus urophylla*, *E. deglupta*, *E. pellita* and *Gmelina arborea*. Despite the high production of the introduced species, the potential of native species has not been exploited and it is rarely considered in reforestation programs.

This paper presents and discusses a mineral nutrition experiments for seedlings of taxi-branco carried out in glass house and silvicultural field information obtained in the State of Para in Brazilian Amazonian.

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Material and Methods

- Mineral nutrition of seedlings

Sub-superficial (0.4 to 0.8 m depth) samples of an Alic Red yellow Latossoil with a clay texture were used from Viçosa, State of Minas Gerais, Brazil (Table 1). The samples were dried, ground to pass through a 4 mm sieve and divided into subsamples of 3.6 kg. The treatments composed by nine combinations of liming and N, P, K and S doses levels were compared to a control that did not receive any liming materials or fertilizers (Table 2). The levels of corrective material were based on soil liming demand (LD) (LD = 2 x Al^{3+} + 2 - (Ca^{2+} + Mg^{2+}).

Table 1. Physical and chemical properties of the an Alic Red yellow Latossoil used in the glass house experiment

Parameter	Unit	Value
pH (1)	-	4.60
Al^{3+}(2)	$cmol.kg^{-1}$	0.78
Ca^{2+} (2)	$cmol.kg^{-1}$	0.04
Mg^{2+} (2)	$cmol.kg^{-1}$	0.02
P (3)	$mg.kg^{-1}$	0.40
K (3)	$mg.kg^{-1}$	5.00
S (4)	$mg.kg^{-1}$	5.10
Organic carbon (5)	%	1.60
Sandy (6)	%	31.00
Silt (6)	%	14.00
Clay (6)	%	55.00
CEC (7)	$cmol.kg^{-1}$	6.57

1) water (1:2.5)
2) Extract. KCl 1.0 N
3) Extract. Mehlich-1
4) Extract. $Ca(H_2PO_4)_2$, 500 mg P kg^{-1} in HOAc 2N
5) Walkley & Black procedure
6) Granumetric fractions
7) Cation-exchange capacity

As a liming was used a mixture of commercial $MgCO_3$ and $CaCO_3$. The N, P and K were applied as salt solutions of $NH_4H_2PO_4$, NaH_2PO_4 H_2O, KH_2PO_4, KCl and NH_4NO_3. The S source was $CaSO_4$ $2H_2O$.

Table 2. Liming demand levels and doses of N, P, K and S applied to soil samples

Liming	Doses Applied ($mg.Kg^{-1}$)			
Demand	P	N	K	S
0.175	180	120	150	60
0.175	420	120	150	60
0.455	180	120	150	60
0.455	420	120	150	60
0.315	300	120	150	60
0.000	180	120	150	60
0.630	420	120	150	60
0.175	30	120	150	60
0.455	570	120	150	60
0.315	300	0	150	60
0.315	300	30	150	60
0.315	300	60	150	60
0.315	300	120	150	60
0.315	300	180	150	60
0.315	300	300	150	60
0.315	300	120	0	60
0.315	300	120	75	60
0.315	300	120	225	60
0.315	300	120	300	60
0.315	300	120	150	60
0.315	300	120	150	30
0.315	300	120	150	90
0.315	300	120	150	120
0	0	0	0	0

In the study of liming and P doses the plants received 80 mg $N.kg^{-1}$, 100 mg $K.kg^{-1}$, and 60 mg $S.kg^{-1}$, while in the study of the response to N, K and S the plants received 300 mg $P.kg^{-1}$ and 0.315 of the liming demand (Table 2).

After the application of the treatments, each experimental plot, consisting of six plastic bags containing 0.6 kg of treated soil, received 18 taxi-branco seeds. Forty-five days after planting was done a pruning, leaving only one plant per bag.

The assays were carried out in a glass house with three replicates. After 190 days of planting the tops of the plants were harvested and the leaves separated from the branches and stems. Soil samples of each plot were taken to evaluate P and K (extraction with Mehlich-1), Ca and Mg (extraction with 1N KCl) and S (extraction with $Ca[H_2PO_4]_2$, 500 ppm of P in HOAc 2N). The plant samples were dried at 70°C, then weighed and ground. From the extract obtained by the nitre-perchloric digestion, K was determined by flame photometry (A.O.A.C., 1975), S by turbidimetry (Blanchar *et al.*, 1965), P by a colorimetric procedure (Braga and Defelipo, 1974), Ca and Mg by atomic absorption and N by Kjeldhal method (Bremner, 1965).

Regression analyses were carried out for leaves dry matter production (LDM), twigs + stems (SDM) and total (TDM) as a function of liming levels and P, N, K and S doses. With these equations, the necessary doses to reach 90% of maximum production were estimated. By substituting the necessary doses of P and K in the regression equation for the recovered P and K in relation to the added P and K doses were determined, the critical levels of these nutrients in the soil. The foliar N, P and K critical values were obtained by substitution of the necessary N, P and K doses in the regression equations adjusted to the foliar N, P and K content, as dependent variables of the doses added to the soil. To choice the equations by the regression analysis, were tested the linear, quadratic and root-quadratic models. The coefficients of the models were examined by F test, using the mean square error of the variance analysis of the experiment.

- Silvicultural information

Silvicultural information were taken from different places in State of Para under homogeneous plantations where the soil was recovered after mined of bauxite and in natural soil conditions.

Results and Discussion

- Mineral nutrition of seedlings

The fertilizers applied resulted in considerable growth gains to the taxi-branco plants and no response to the addition of lime (Table 3). The absence of response may be related to the fact that these treatments received 60 mg $S.kg^{-1}$ as gypsum. The Ca content in this salt (0.37 $cmol.kg^{-1}$) was sufficient for the requirements of taxi-branco and, as the soil used contained low levels of Ca (0.04 $cmol.kg^{-1}$), it follows that seedlings of taxi-branco have a low requirement for this nutrient.

Increments of P doses resulted in increments of P foliar contents (Table 4). The soil critical level of P was 26.06 $mg.kg^{-1}$ using the model adjusted for TDM, and 0.12% of the critical foliar P content with the model adjusted for LDM. These values were close to those observed by Novais *et al.* (1982) for *Eucalyptus* sp.

Table 3. Regression equations adjusted for the production of total dry matter ($g.pot^{-1}$) of the aerial parts (TDM) as dependent variables of levels of liming and P, N and K doses

Regression Equation	R^2
Response to liming and P applied	
$TMD= 3.71699 + 0.05134^{***} P - 0.000059^{*} P^2$	0.9444
Response to N applied	
$TMD = 9.40775 + 0.05735^{**} N - 0.000166^{*} N^2$	0.8390
Response to K applied	
$TMD= 9.92005 + 0.04669^{*} K - 0.000125^{\circ} K^2$	0.9088

° Significant at 0.1 probability level
* Significant at 0.05 probability level
** Significant at 0.01 probability level
*** Significant at 0.005 probability level

The positive response of N addition can be confirmed by the equation for TDM as variables dependent on the N doses added to the soil (Table 3). In accordance with this model, 90% of maximum production (12.92g) obtained can be obtained by one dose dose around 79 mg of N kg^{-1} of soil.

Table 4. Regression equations adjusted for the P, Ca, Mg, N and K concentrations (%), in the dry matter of leaves and twigs + stems, as dependent variables of the applied doses of N and K

Regression Equation	R^2
$P = 0.05855 + 0.000335^{***} P - 0.00000042^{*} P^2$	0.8825
$Ca = 0.1745 + 0.00103^{*} P + 1.16715^{***} NC - 0.00000187^{*} P^2 - 0.95461^{\circ} NC^2$	0.9088
$Mg = 0.0802 - 0.00011^{***} P + 0.08953^{***} NC + + 0.00000016^{**} P^2 - 0.07326^{\circ} NC^2$	0.9725
$N = 1.41731 + 0.011643^{***} N - 0.0000213^{*} N^2$	0.9616
$K = 0.28103 + 0.004501^{***} K + 0.0000093^{***} K^2$	0.9582

° Significant at 0.1 probability level
* Significant at 0.05 probability level
** Significant at 0.01 probability level
*** Significant at 0.005 probability level

In spite of a quadratic response to the N addition, taxi-branco is regarded as a legume tree with the capacity to associate with atmospheric N_2-fixing bacteria. Therefore, if Rhizobium inoculated seeds were to be used, the plants may exhibit a different response to the addition of these nutrients.

According to the adjusted model for TDM as the dependent variable of K doses (Table 3), the soil critical level obtained for this nutrient was 27.4 $mg.kg^{-1}$. This value is close to that obtained by Barros *et al.* (1982) for *Eucalyptus grandis.*

The N and K contents in the tops of the plants increased with increasing doses of these nutrients (Table 4). On the other hand, this was not observed for the S contents in the aerial parts of the plants, since they did not alter significantly with the different S doses applied.

As the recommended N and K doses (79 mg $N.kg^{-1}$ and 80 mg $K.kg^{-1}$) are substituted in the adjusted equations for N and K foliar contents as dependent variables of the applied doses (Table 4), the critical foliar levels of 2.2% of N and 0.7% of K were obtained.

The absence of response to the S doses can be seen by the lack of adjustment of significant mathematical models for the different analyses of variables. This indicates that the original S content in the soil was higher than the critical level for taxi-branco. On the other hand, the adjusted equation for the S recovered from the soil by the extractant, as a function of the applied doses (Table 5), shows an increase of the availability of this nutrient with the doses. Therefore, it can be suggested that the critical S level for taxi-branco is lower than 5.1 $mg.kg^{-1}$ of soil.

With the same extractant from a soil with a clay content similar to that used in the present study (53%), Alvarez *et al.* (1983) obtained a critical S level of 5.3 $mg.kg^{-1}$ of soil for 90% of maximum production of *Eucalyptus grandis* seedlings.

Table 5. Regression equations adjusted for the P, Ca, Mg, K and S recovered from the soil by the extractants, as dependent variables of the applied levels of liming and P, K and S doses

Regression Equation	R^2
$P = - 5.62804 + 0.114598^{***} P$	0.9198
$Ca = 0.24512 + 1.51045^{***} NC$	0.9899
$Mg = - 0.023941 + 0.46401^{***} NC$	0.9590
$K = 4.4099 + 0.2362^{***} K + 0.00064^{**} K^2$	0.9986
$S = 4.5943 + 0.0680^{*} S + 0.00058^{*} S^2$	0.9899

* Significant at 0.05 probability level
** Significant at 0.01 probability level
*** Significant at 0.005 probability level

- Silvicultural information

Sclerolobium paniculatum Vogel has four varieties (paniculatum, subvelutinum, rubinosum, and peruvianum) with the difference found mainly in the characteristics of the leaflets. The States of Pará and Amazonas in Brazil are the main regions where the paniculatum variety occurs (Pereira, 1990).

In homogenous plantations taxi-branco has an architecture similar to eucalyptus plantations. The adult trees found near Santarem, possess heights varying between 20 m and 30 m and a Diameter at Breast Height (DBH) of 70 to 100 cm. In secondary succession occupies open spaces and is characterised as a light demanding species, with a great capacity for adaptation in unfavourable soil conditions (Carpanezzi et al., 1983; Erfurth & Rusche, 1976; Lemeé, 1956; Ducke, 1949 and Correa, 1931).

Phenology observations in Trombetas National Forestry indicated that flowering occours between may throught july and frut production in August until November (Mineração Rio do Norte, sn). In Santarem region, near Trombetas National Forestry, fruit matures and the dissemination of the seeds occurs from January to March.

The taxi-branco seeds are small and hard. It was observed about 15,000 seeds per kilo (Mineração Rio do Norte, sn).

The mechanical dormancy of seeds can be overcome with the application of adequate technologies (Carpanezzi et al., 1983 and Carvalho & Figueiredo, 1991) and its germination occurs in approximately 30 days.

Field experimentation has shown good silvicultural performance in relation to other species considered pioneers in secondary succession (Tables 6 and 7). The analysis of the performance of taxi-branco with other native species must consider the fact that, seeds from mother trees, chosen in locals of natural occurrence were used and therefore there is a low index for genetic selection. So, the development of studies for genetic improvement to the determination of better provenance and adequate silvicultural practises, may improve, even further, the performance of taxi-branco.

Taxi-branco has showed its potential for reclamation of degraded land in a trial held in abandoned pasture in Paragominas (Table 8). This behavior can be due to its capacity to fix nitrogen and to associate to endomicorizal fungi (Table 9).

Table 6. Increments average values of plant height (m) and Diameter at Breast height (DBH) (cm) for taxi-branco at different ages (months) planted in Belterra

Age	Plant height	Plant DBH
24	1.00	2.80
60	2.40	3.70
72	1.90	3.80
108	1.80	2.80
180	1.10	2.50

Adapted from Matos (1993)

Table 7. Average values for survival (%), height (m), DBH (cm) and volume (m^3/ha) in different ages for some native and exotic species of rapid growth planted with a 3 m x 2 m spacing at Belterra, State of Para

Species	Age	Survival	Height	Dbh	Volume
Vismiasp	66	91,7	8,6	7,6	31,9
Laetia procera	66	96,7	7,6	8,6	36,9
Acacia mangium	30	97,0	7,4	10,7	58,2
S. paniculatum	66	94,7	12,2	9,1	105,7
E.urophylla	78	85,5	13,4	13,2	167,2
Jacaranda copaia	78	94,7	12,4	14,5	175,2
Eucalyptus grandis	78	74,7	16,0	16,0	257,2

Adapted from Yared et al. (1988)

Table 8. Growing of height (m), DBH (cm) and dossel area projection (m^2) of eight forestry species planted directly in abandoned pasture in Paragominas

Specie	Height	DBH
*Tabebuia serratifolia**	2.80	1.80
*Bertholletia excelsa**	3.30	5.10
*Dipteryx odorata**	3.60	3.30
*Cedrela odorata**	4.00	4.70
*Swietenia macrophylla**	6.30	6.30
*Sclerolobium paniculatum***	6.40	8.70

* plants with five years old

** plants with three years old

Adapted from Pereira & Uhl, in press

Table 9. Root infection of endomicorize fungi of fast growth tree species planted in abandoned pasture in Paragominas

Specie	Root infection (%)
Swietenia macrophyla	90.0
Cecropia palmata	86.0
Cordia multispicata	82.0
Solanum crinitum	80.2
Anacardium occidentale	80.8
Bertholletia excelsa	79.8
Dipterix odorata	74.2
Acacia mangium	65.7
Sclerolobium paniculatum	58.3
Stryphenodendrum pulcherrimun	57.8
Cariocar vilosum	56.2
Dydimopanax morototoni	56.0
Schyzolobium amazonicum	49.7

Adapted from Oliveira Júnior (unpublished data)

The biomass of taxi-branco trees is proportionally greater for the trunk (247.01 kg), branches (97.81 kg) and leaves (22.13 kg). The greatest concentrations of nutrients were found in the leaves followed by the branches and trunk. Nitrogen was the nutrient observed in the greatest proportion in the different parts of the plant (Matos, 1993).

In homogenous plantation at the Experimental Station in Belterra, the litter production of taxi-branco was about 2.7 times greater than *Eucalyptus citriodora* (Table 10). Besides this, the chemical composition of the litter incorporated to the soil is another important characteristic to be considered. This has immediate implications in relation to its ability for decomposition and augmentation of organic material to the soil, especially when one is dealing with recuperating degraded soils. In this context, when comparing the chemical composition of the litter of taxi-branco with that of *E. citriodora*, one can verify the advantage of using a leguminous specie for the recuperation of soil fertility (Table 10). Although taxi-branco has low ratio of C/N, that facilitates decomposition, the high quantities of N, P, K, Ca and Mg on litter that reach the soil are superior to those of eucalyptus (Table 10).

Table 10. Production of litter ($t.ha^{-1}.yr^{-1}$), C/N ratio in litter and quantities ($t.ha^{-1}.yr^{-1}$) of N, P, K, Ca and Mg in litter of homogenous plantations of taxi-branco and *E. citriodora* at Belterra, State of Para

Parameter	Species	
	Taxi-branco	E. citriodora
Production of litter	7.7	3.3
C/N ratio	40.0	69.0
N	32.0	28.0
P	2.3	1.0
K	3.9	2.3
Ca	13.9	13.7
Mg	5.4	3.3

Brienza & Yared (unpublished data)

The potential of taxi-branco for the recuperation of degraded soils has been confirmed with plantations in areas where bauxite has been mined by Mineração Rio do Norte, in Porto Trombetas. Among the different native species used, taxi-branco has been prominent (Table 11). The rapid formation of litter may provide favourable conditions for establishment of other pioneer species in order to promote the increase of biodiversity in an imitation of the natural succession process.

Table 11. Growth in height (m) and diameter at breast height-Dbh (cm) at seventy month of different native tree species planted in area with superficial top soil after buxite mined

Specie	Height	Dbh
Himenolobium excelsum	5.20	8.0
Miconia longifolia	9.40	11.0
Bowdichia sp	6.50	8.0
Sclerolobium racemosa	10.60	26.6

Adapted from Knowles (1994)

A study of undisturbed soil samples, collected under different vegetation after the exploitation of bauxite in Porto Trombetas, using *Acacia auriculiformis* as an plant indicator, suggest that the *A. auriculiformis* growth was probably favoured by the better soil conditions promoted by taxi-branco (Table 12).

Table 12. Height, roduction of dry matter of roots and aerial parts of *Acacia auriculiformis* planted in no-modified soil collected under: natural regeneration (NR); homogeneous stands of taxi-branco; mixed plantings of native species (MPN); mixed plantings with exotic species (MPE) and homogeneous stand of *Acacia mangium*, at the Mineração Rio do Norte in Porto-Trombetas

Soil type	Height (cm)	Aerial dry matter (g)	Root dry matter (g)
NR	17.3	2.6	0.6
Taxi-branco	16.5	2.5	0.4
MPN	14.3	2.2	0.3
MPE	13.6	2.2	0.3
Acacia mangium	8.7	1.5	0.1

Conclusion

The results of this work permitted the determination of the critical levels of P and K in the soil for taxi-branco, as being 26.1 and 27.4 $mg.kg^{-1}$ of soil respectively. The N dose required to obtain 90% of maximum production of total dry matter was 79 mg kg^{-1} of soil. The N, P and K critical foliar contents were 2.20%, 0.12% and 0.70% respectively. Because of the absence of response to liming and S addition, the Ca and S critical levels were estimated as being lower than 0.37 $cmol.kg^{-1}$ and 5.1 $mg.kg^{-1}$ of soil respectively.

The low Ca requirements of taxi-branco, its tolerance for exchangeable Al in the order of 1 meq/100 cm^3 of soil, its capacity fix N and associate with micorizal fungi are certainly factors which contribute to its success as a pioneer in secondary succession, especially in conditions of low soil fertility, as was confirmed based on Trombetas, Belterra and Paragominas plantations and experimentations.

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