Proceedings
of the
Third SHIFT-Workshop
Manaus
March 15 - 19, 1998

A German - Brazilian
Research Program

Biomass production and nutrition aspects of plantation trees in Amazonia

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ABSTRACT

The present study was directed to establish a correlation between the nutrient content and the biomass of plantation trees. This was done in order to predict and to influence the wood quality to be expected already at an early growth stage.

The development of biomass production of *Ceiba pentandra* (L.) Gaertn. and *Virola surinamensis* (Rottb.) Warb. was studied under monocultural conditions at an experimental field of EMBRAPA Amazônia Ocidental, Manaus. Subsequently, the data were related to the nutrient supply after 45 and 65 months respectively. It could be shown that the supply of the trees, especially with K and P, is restricted. The percentile content per dry weight biomass of the two macronutrients P and Mg decreases remarkably between 45 and 65 months of plant age. In addition, the recycling of P, K, Ca, Mg, and S from litter fall amounts to distinctly higher figures in *Ceiba* than in *Virola.*

The findings of the correlation between the biomass and nutrient content indicate the need of fertilization in order to guarantee sustainable growth of high quality wood species.

RESUMO

Neste trabalho compara-se duas espécies arbóreas de plantação respeito à correlação entre o teor de elementos minerais tanto no solo como na planta, e a biomassa producida pela mesma. O objetivo principal deste estudo era interpretar os resultados obtidos com plantas ainda na fase de crecimento juvenil relativo às propriedades da madeira da planta adulta, além de indicar as possibilidades de influenciar tais propriedades.

Para tal fim foi estudado o desenvolvimento da biomassa das duas espécies *Ceiba pentandra* (L.) Gaertn. e *Virola surinamensis* (Rottb.) Warb., ambas provenientes de plantações tipo monocultura establecidas em um campo experimental do EMBRAPA Amazônia Ocidental cerca de Manaus, AM. A correlação entre elementos minerais e biomassa producida foi determinada com plantas de 45 e 65 meses de idade, respeitivamente, dando como resultado uma decrécimo notável em potássio (K) e fósforo (P) neste período ou seja, a percentagem dos dois macro elementos minerais em relação a biomassa (peso seco) producida diminuíu consideravelmente entre idade 45 e 65 meses. Além disso, as duas espécies estudadas mostraram uma capacidade diferente de reciclagem de elementos minerais em geral, sendo a *Ceiba pentandra* muito mais eficiente respeito à reabsorção dos elementos P. K, Ca, Mg, e S da folhagem descartada pelas árvores.

Estos resultados assinalam a necessidade de fertilização periódica das plantações para segurar um crescimento sustentável em monoculturas destas duas espécies.

ZUSAMMENFASSUNG

In der vorliegenden Untersuchung wurde überprüft, inwieweit eine Korrelation zwischen Nährelementgehalt und Biomasse von zwei Plantagenbaumarten besteht. Das Ziel war, bereits aus der juvenilen Wachstumsphase auf die Holzeigenschaften der adulten Pflanze zu schließen und Möglichkeiten einer Beeinflussung der Holzeigenschaften aufzuzeigen.

Die Entwicklung der Biomasse wurde unter Monokulturbedingungen auf einer Versuchsfläche der EMBRAPA Amazônia Ocidental, Manaus, für *Ceiba pentandra* (L.) Gaertn. und *Virola surinamensis* (Rottb.) Warb. untersucht. Nach 45 bzw. 65 Monaten Versuchsdauer wurde die Nährelementversorgung in Beziehung zur Biomasse gesetzt. Es ergab sich ein sehr unzureichendes K- und P-Angebot. Der prozentuale Gehalt der beiden Makronährelemente pro Trockengewicht Biomasse Baum verringerte sich zwischen den Monaten 45 und 65 beträchtlich. Zwischen den beiden Baumarten zeichnete sich eine unterschiedliche Fähigkeit zum Recycling der geprüften Makronährelemente ab. *Ceiba* konnte die Elemente P, K, Ca, Mg und S aus dem Laubfall wesentlich besser als *Virola* erneut aufnehmen.

Diese Befunde weisen deutlich darauf hin, daß die Versuchsflächen gedüngt werden müssen, um ein nachhaltiges Wachstum dieser Baumarten sicherzustellen.

INTRODUCTION

For the selection of wood species which can be used in different afforestations some questions of fundamental importance should be mentioned, as to: 1 - the objective of the plantation, 2 - which species are available to reach this goal and 3 - their future behavior at the site in question. Certainly, the last question requires knowledge of the adaptation of the species in edafo-climate conditions where they are to grow.

In Amazonia, the knowledge on the influence of the abiotic factors on the growth and wood formation of forest species is still at an initial stage. For this reason, scientists of the Agroforestry Research Center of West Amazonia - EMBRAPA since January 1995 are investigating the above mentioned factors for the following species: *Swietenia macrophylla* (Mogno), *Carapa guianensis* (Andiroba), *Cedrela odorata* (Cedro), *Dipteryx odorata* (Cumaru), *Hymenaea courbaril* (Jatobá), *Tabebuia heptaphylla* (Ipê), *Ceiba pentandra* (Sumaúma) and *Virola surinamensis* (Virola) in cooperation with the Institute of Wood Biology of Hamburg University through the SHIFT Project ENV 42.

The objective of this work is to present some results for the species *Ceiba pentandra* and *Virola surinamensis*, referring to:

1. the production and distribution of the biomass, 45 and 65 months after planting
2. the concentration of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), and aluminium (Al) in the soil solution
3. the measured contents of P, K, Ca, Mg, S and Al in these species, 45 and 65 months after the plantation begins, and
4. the contents of P, K, Ca, Mg, S and Al returned to the soil by litter fall.

MATERIAL AND METHODS

The experiment was realized on the experimental field in the Agroforestry Research Center in Amazonia - EMBRAPA/ West Amazonia, located between the co-ordinates 03°00´00" and 03°08´00" of South latitude and 59°52´40" and 59°58´00" of East longitude and at an altitude of 50 mNN, Manaus - AM. The plants were produced in the nursery with seeds from Manaus and Santarém and, at ages varying between 4 and 6 months, were taken to the field in June 1992. The design was randomized with parcels of 225 m^2, which contained 25 plants with a distance of 3 to 3 m and 4 repetitions.

The climate of the area is classified as Afi via the system of Köppen. Observations made between January 1992 and December 1996 registered a precipitation with an annual average of almost 2,720 mm and an average of maximum and minimum temperatures of 34.1°C and 20.3°C, respectively. The relief is plane and the soil was classified as Latossolo Amarelo Distrófico with a very argillaceous texture (Rodrigues et al. 1972). Chemical analyses of soil which was sampled during the planting showed the following results: pH (H_2O) 4.5; N = 0.17%; P = 1 and K = 20 mg Kg^{-1}; Ca = 0.26; Mg = 0.11 and Al = 1.7 $Cmol_c$ Kg^{-1}.

The biomass production of the leaves, branches, stem and roots of the studied species was calculated after the felling of a tree in the years 1995 to 1997, selected according to the methodology proposed by Kramer and Akça (1985). The samples of the referring fractions were prepared according to Rademacher (1986) and analyzed with Optical Emission Spectrometry with Inductively Coupled Plasma Flame (ICP-OES). The total amount of each element in the trees were calculated by multiplying the measured concentration of each element with the biomass production.

The concentration of P, K, Ca, Mg, S and Al in the soil solution was measured with Optical Emission Spectrometry with Inductively Coupled Plasma Flame (ICP-OES). The solutions were collected with tensiometers, which were installed in a depth of 20 cm and at a distance of 50 to 150 cm from the studied species. The samples were collected weekly during a period between May 1995 and April 1996 and analyzed.

The litter fall was collected monthly during a period between July 1995 and June 1996 with nylon nets having a rectangular form (2.4 m x 3 m) and being fixed in a height of 50 cm on wood sticks which were installed in the plots of the studied species. After these preparations, the samples were analyzed with ICP-OES to quantify the nutrient entering into the soil.

RESULTS AND DISCUSSION

1. Biomass production and its portion in the different plant compartments

Table 1 demonstrates that, while changing the age, *Ceiba pentandra* shows a percentile increase in the biomass production of wood and bark of the stem and wood of the roots, while in *Virola surinamensis* this increment occurs only in the wood and bark of the roots. With relation to the economic and silvicultural aspects, the percentile increment of the wood biomass from the stem of *C. pentandra* is of mayor importance. The observed percentile increase in wood and bark biomass in roots of *V. surinamensis* might reflect a strategy of establishment of this species. The decrease in the leaf biomass of the studied species is a result of the natural process of branch loosing and events when branches were broken by the wind, especially the ones from *C. pentandra*.

Table 1: Biomass of leaves, branch wood, branch bark, stem wood, stem bark, root wood, root bark and fine roots of *Ceiba pentandra* and *Virola surinamensis* planted in the plain soil at ages of 45 and 65 months.

Age (months)	Species	Biomass distribution of the tree (%)							
		leaves	branche swood	branche sbark	stem wood	stem bark	roots wood	roots bark	fine roots
45	**Ceiba**	7.08	12.24	4.69	43.92	8.36	19.09	4.39	0.22
65	*Ceiba*	4.88	5.81	2.10	48.43	15.57	19.93	3.23	0.05
45	*Virola*	16.88	14.72	2.84	38.57	5.09	16.91	1.88	3.11
65	*Virola*	9.43	15.65	1.24	32.98	4.82	30.58	3.78	1.52

2. Concentration of P, K, Ca, Mg, S, and Al in the soil solution

The results of the analysis of the studied bio-elements of the soil solution are presented in table 2. Compared to studies of Mc Laughlin (1985) and Rademacher et al. (1986), the amounts of those elements are lower than the ones observed in soils of temperate forests.

According to Marschner (1995), it can be observed that the measured concentrations are lower than the amount which would be necessary for an optimal growth of these plants. Especially the low supply of P and K can limit the growth of the studied species.

Table 2: Concentration of P, K, Ca, Mg, S and Al (µg/g) in the soil solution in a depth of 20 cm referred to the period of May 1995 and April 1996.

Depth (cm)	Species	Concentration of the elements (µg/g)					
		P	K	Ca	Mg	S	Al
20	**Ceiba**	0.02	0.57	1.92	0.62	0.22	0.00
20	**Virola**	0.02	0.62	2.28	0.76	0.20	0.00

3. Measured contents of P, K, Ca, Mg, S, and Al in the studied species

Table 3 demonstrates that in *Ceiba pentandra,* the nutrient content per produced biomass increased with age for K, Ca, and S and decreased in P, Mg and Al, while in *Virola surinamensis* it increased only for K and decreased in the other nutrients. In this second species, the observed Al content is very high. The results let assume that this species is tolerant with respect to this element.

The differences in the contents of K and P during increasing age measured for *Ceiba,* as well as for *Virola,* are remarkable. The absolute rates of P-content in the plant already decreases at an age of 65 months, and also the K supply of the plant is seriously restricted at this age. This tendency is also true for the Ca-, Mg-, and S-content per plant. By this, it can be confirmed that the growth of the species is especially limited through the supply with P and K.

Table 3: Data of the content of P, K, Ca, Mg, S, and Al (mg/ kg) in *C. pentandra* and *V. surinamensis* 45 and 65 months after planting.

Species	Age (months)	Nutrient contents (mg/ kg dry weight)					
		P	K	Ca	Mg	S	Al
Ceiba	45	1,078	6,642	7,844	1,520	596	653
Ceiba	65	1,025	6,866	9,683	1,367	603	478
Virola	45	1,226	4,433	6,611	1,821	780	1,890
Virola	65	1,001	4,500	4,978	1,584	648	1,387

4. Contents of P, K, Ca, Mg, S, and Al in the litter fall

According to Jordan (1982) and Lambrecht (1986), the nutrient cycle through litter fall is a principal source for the supply with mineral elements for plants in the tropical ecosystems.

As compared in table 4, the litter of *Ceiba pentandra* in all the studied elements presents higher quantities than the ones represented by *Virola surinamensis*. This evident fact lets assume that the deposition of nutrients through litter is more intensive in *C. pentandra* than in *V. surinamensis*. It seems that the leaves of *Ceiba pentandra* do enter the stage of senescence earlier than the ones of *Virola surinamensis*. High contents were found for Ca, K, Mg, and S, as well. However, it is obvious that only a minor part, in particular of K and Mg, can be recycled by *Virola*. It is indicated that the output in the soil is significant.

Table 4: Contents of P, K, Ca, Mg, S and Al (mg/m^2) existing in the litter of *Ceiba pentandra* and *Virola surinamensis*, referred to the period between July 1995 and June 1996.

Species	Nutrient contents (mg/m^2)					
	P	K	Ca	Mg	S	Al
Ceiba	185	878	3,098	889	283	18
Virola	23	91	535	195	42	3

CONCLUSION

The analysis of the data given in this work permits the following conclusions:

- In *Ceiba pentandra*, a percentile increase in the biomass production of wood and bark of the stem and the wood of the roots occurs between the age of 45 and 64 months, while in *Virola surinamensis* this increase (indicated in [%]) occurs only in the wood and bark of the roots.
- The concentrations of P, K, Ca, Mg, S, and Al existing in the soil solution are below the amount necessary for the optimal growth of the plants. Especially the low supply of P and K can limit the growth of the studied species.
- In *Ceiba pentandra*, the measured nutrient concentration in the produced biomass only slightly increased for K, Ca and S and decreased for P, Mg, and Al; while in *Virola surinamensis* the increase only occurred for K and decreased for P, Ca, Mg, S, and Al.

Meanwhile, the high content of Al observed in *V. surinamensis* suggests a tolerance for this element.

- The contents of P, K, Ca, Mg, S, and Al measured in the litter of *Ceiba pentandra* are higher than the ones of *Virola surinamensis*. There is a probability that the leaves of *C. pentandra* are entering the stage of senescence earlier than the ones of *Virola surinamensis*.

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