

2. Results

Development of tree height and diameter of eight selected tree species under plantation conditions in Central Amazonia

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Summary

In 1992/ 93, studies on the recultivation by forest trees on abandoned and/ or degraded areas were executed at the experimental field of the EMBRAPA Amazônia Ocidental, Manaus. The main aim was to study the growth behaviour, as concerns height and diameter, of twenty forest species in different plantation systems (monoculture, mixed culture, and enrichment culture). For the monoculture and the enrichment culture, a complete randomized plot design with four repetitions was used, and in the mixed culture, a complete randomized block design with five repetitions was selected.

Since January 1995, within the scientific Brazilian-German cooperation program SHIFT, the growth of eight of these twenty species (*Carapa guianensis* Aubl., *Cedrela odorata* L., *Ceiba pentandra* (L.) Gaertn., *Dipteryx odorata* (Aubl.) Willd., *Hymenaea courbaril* L., *Swietenia macrophylla* King, *Tabebuia heptaphylla* (Vell.) Tol., and *Virola surinamensis* (Rol.) Warb.), planted in the three different systems, was investigated. In this publication, the initial results of tree diameter and height, survival, and incidence of weed and diseases of the species during the first four and five years respectively, are presented. The parameters diameter at breast height (DBH), height and basal area differ considerably among the species and between the plantation systems, which suggests that they might be criteria for the selection of the species to be planted in each plantation system. In the monocultures, the best results of growth and survival of the species were registered in comparison to the enrichment cultures and the mixed culture. Among the species planted, *Carapa guianensis* revealed the highest increment. In the monoculture system, *Ceiba pentandra* also showed outstanding results. The *Meliaceae* (*S. macrophylla*, *C. guianensis*, and *C. odorata*) were entirely attacked by *Hypsipyla grandella* (*Lepidoptero*) to 100% of its trees, independently of the plantation system, causing high mortality among trees of *S. macrophylla*. *Lepidoptero* causes the „broca dos ponteiros“, which means the destruction of the apex meristem that reduces growth. In addition, it induces the bad habitus of the trees which as a rule leads to commercial loss in value.

Resumo

Desenvolvimento em altura e diâmetro de árvores de oito espécies selecionadas sob condições de plantação na Amazônia Central

No campo experimental do EMBRAPA Amazônia Ocidental, Manaus, instalaram-se em 1992/ 93 ensaios (agro)florestais sobre áreas abandonadas e/ ou degradadas, com objetivo de conhecer o comportamento de vinte espécies florestais em diferentes sistemas de plantações (plena abertura, plantio misto e faixas de enriquecimento). Nos plantios à plena abertura e faixas de enriquecimento, utilizou-se o delineamento inteiramente casualizado com quatro repetições e no sistema misto, o delineamento em blocos ao acaso com cinco repetições.

Desde Janeiro de 1995, no acordo de cooperação científica Brasil-Alemanha, programa "SHIFT" tem sido investigado o crescimento de oito destas vinte espécies (*Carapa guianensis* Aubl., *Cedrela odorata* L., *Ceiba pentandra* (L.) Gaertn., *Dipteryx odorata* (Aubl.) Willd., *Hymenaea courbaril* L., *Swietenia macrophylla* King, *Tabebuia heptaphylla* (Vell.) Tol., e *Virola*

surinamensis (Rol.) Warb.), plantadas nos três diferentes sistemas de plantios. Apresentam-se os resultados iniciais do crescimento em diâmetro e altura, sobrevivência e incidência de pragas e doenças das espécies durante os primeiros quatro e cinco anos de idade, organizados por espécies e sistemas de plantação. Os parâmetros DAP, altura, área basal e respectivos incrementos médios, variaram muito entre as espécies e entre os sistemas de plantação, o qual sugere uma seleção muito criteriosa da espécie a ser plantada em cada sistema de plantação. Nos plantios a plena abertura, registraram-se os melhores resultados de crescimentos e sobrevivência das espécies em comparação com os obtidos nas faixas de enriquecimento e plantio misto. Entre as espécies plantadas a *C. guianensis* apresentou o melhor resultado nos três sistemas de plantio. Entretanto, no sistema de monocultivo, a *C. pentandra* mostrou os melhores resultados. As *Meliaceae* (*S. macrophylla*, *C. guianensis* e *C. odorata*) tiveram 100% das suas árvores atacadas por *Hypsipyla grandella* (*Lepidoptero*) independente do sistema de plantação causando alta mortalidade, principalmente, para as árvores de *S. macrophylla*. Este *lepidoptero* causa a broca dos ponteiros, ocasionando a destruição do meristema apical que retarda o crescimento e induz a má formação das árvores, as quais usualmente produzem bifurcações e/ ou ramificações excessivas e conseqüente desvalorização comercial da madeira.

Introduction

Within the latitudes 23,5° N and 23,5° S that include part of Central America, South America, Africa, Australia, India, and South East Asia, there are around 650 million hectares land used as growing areas and almost two billion hectares in different stages of degradation (VIDAKOVIC, 1986; according to JESUS, 1992).

The increasing demand for wood and agricultural areas and the population growth in the Amazon region in the last 20 years have caused a significant increase in destroyed forest areas in different degrees of degradation. In December 1996, a percentage of 13% of the original forest was reached, corresponding to 517,069 km².

At the forest in question, the great concentration of species can be recognized, as well as the quick loss of the vegetation diversity. The majority of these species were already described botanically, but little studied with regard to the silvicultural aspects. The lack of information about the nutritional necessities of each species leads to a void in knowledge about those species (MONTAGNINI, 1992).

On account of this development, silvicultural and agroforestry systems constitute the alternatives to incorporate these areas in a productive system, in a way to increase or sustain the land productivity without causing degradation (MONTAGNINI, 1992).

The use of agroforestry systems implies the selection of appropriate species. However, there is few biological information on potential forest species for use in these systems, especially in the Amazon region (MARQUES, 1990). The research in silviculture has contemplated comparative studies on tests of native and exotic species. The majority of them was exposed to sunny conditions, others to partial shadow in secondary vegetation (YARED et al., 1988; SAMPAIO et al., 1991; NEVES et al., 1993). The lack of knowledge on forest species that can be used under sunny conditions has made the use of nonproductive areas difficult. From the species investigated by CPATU (KANASHIRO and YARED, 1991) and INPA (JANSEN and ALENCAR, 1991), few are effectively used in forest culture.

So far, the recommendation of forest species for plantations in the Amazon region is based on the experience derived from only a few field experiments and from ecological areas to reforest in Brazil (GOLFARI et al., 1978). The recommendation of suitable species is limited especially by the conifers and eucalypts.

The inadequacy of silvicultural information about native species is normally mentioned as one of the causes for reforestation. ALENCAR et al. (1979) believe that to get adequate genetic material for plantation poses severe problems.

EMBRAPA Amazônia Ocidental began in 1991. It is a Forest Test Project to study the adaptability of different forest species commonly planted in the tropics, species with commercial values and lesser known native species.

In the present study, the results on height and diameter growth of eight species of high commercial value (*mogno*, *cedro*, *andiroba*, *cumaru*, *jatobá*, *sumaúma*, *ucúuba*, and *ipé*) are presented for three different culture systems in relation to survival and occurrence of weeds and diseases.

Characteristics of the planted species

Carapa guianensis Aubl. – *Meliaceae* (Andiroba)

Andiroba is a fast-growing and tall tree, reaching 30 m in height, with a thick and bitter bark. It frequently forms associations. The species is of great commercial value because of its abundance and the oil content of the seeds and its wood quality. Andiroba occurs naturally in the Manaus region in the shallow Amazon and Solimões river, and in the upper Erepecuru river. It is frequent at the north coast of Para State, the shallow Tocantins river, until Maranhão State, Central America and the West Indies. In general, it is distributed from Belize and Honduras to Ecuador, Peru, Brazil and the Guineas, the West Indies, Cuba, Dominican Republic, Haiti, Guadeloupe, Dominique, San Vincent, and Trinidad.

According to LOUREIRO and SILVA (1968), the andiroba wood is moderately heavy (0.68 – 0.75 g/ cm³). It is generally used for joinery products, inside construction, for plywood, furniture, canoes, squares, pencils etc.

Cedrela odorata L. – *Meliaceae* (Cedro)

Cedro is a fast-growing, large tree of 30 – 35 m height. The species prefers deep and damp soils. In the Amazon, it is found on the clay soil of the „terra firme“ and also on sandy soil, being also frequent on the inundated banks of some rivers (LOUREIRO et al., 1979).

The common utilization is for plywood, squares, intern work, cigar box, carpentry, and soft raft. Similar to mogno, it has high commercial value and is widely used by wood industries of the region (LOUREIRO and SILVA, 1968). The seeds can be used, as well.

Ceiba pentandra (L.) Gaertn. – *Bombabaceae* (Sumaúma)

Ceiba is a fast-growing tree. On the terra firme, the species is of a minor size compared to trees on the flood plain land, although it is bulky. During the juvenile phase, the branches and trunk develop thick conic thorns. Naturally, the species is found in Mexico, in the south of Central America to Colombia, Venezuela, and Ecuador. It also occurs on the east coast of Africa, on Andaman Island and a Malayan Peninsula. The tree species is introduced on the Bermudas and the Bahamas and cultivated in Florida and California. It prefers the flooded or swampy plains, and it also occurs on the upper „terra firme“ with clay and fertile soil (LOUREIRO et al., 1979).

According to LOUREIRO and SILVA (1968), the wood is very light (0.30 to 0.37 g/ cm³) and is used in the raft-shift construction, for boxes, toys, barrels of short life, plywood and the production of cellulose.

Dipteryx odorata (Aubl.) Willd. – *Fabaceae* (Cumaru)

Cumaru is a tall tree of 30 m height. The species is considered in the reforestation. It blossoms early, already at an age of four years, developing aromatic seeds, from which an essential oil, which is used in perfumery (cumarina) can be extracted.

The hard wood, as one of the best wood species, contains a high natural durability, and it does not develop cracks when exposed to the sun. It is used for agricultural implements, in naval construction, joinery, carpentry, for laminated articles, handle tools, fence rails, wagons, stakes, etc. (LOUREIRO et al., 1979).

***Hymenaea courbaril* L. – *Caesalpinaceae* (Jatobá)**

Jatobá is a tall tree that can reach a height from 10 to 25 m and a diameter of 1 m or more. It is especially characterized by its resin called „jutaí-cica“ or „copal of America“, which is used industrially for varnish of inferior quality and for medical uses. The species is distributed geographically from Mexico, across Central America, occurring widely at the Hiléia, reaching down to São Paulo. It also is found in the Guineas, Surinam, Venezuela, Colombia, the West Indies and Bolivia. It inhabits the terra firme land; frequently occurring in clay soil and at some upper plains. However, it is rare in fields and „capoeiras“, where the tree exhibits minor portions.

In general, the wood is used in hydraulic works, wagons, pillars, cask barrels, all kinds of construction, furniture, laminates, props, timber work, instruments, piano construction, and stakes (LOUREIRO et al., 1979).

***Swietenia macrophylla* King – *Meliaceae* (Mogno)**

This species exhibits trees of 30 – 50 m height and 50 – 200 cm in diameter. It has a very large distribution in Colombia, Venezuela, Peru, and Brazil. In Brazil, its distribution reaches to the superior basin of Juruá and Purus, passes the basin of median Madeira, north of Mato Grosso and south of Pará (basin of upper Tapajós and upper Xingu) and extends to the northeast until the Tocantins and the Balsas river. It often occurs on solid land, sometimes in swampy areas, but frequently at “ribanceiras” and slopes well-drained that receive heavy precipitation (LOUREIRO et al., 1979).

Mogno shows a moderate natural durability against fungal and insect attacks. It is used as veneer for luxury furniture, civil constructions, inside decorations, scientific instruments of high precision, aviation industry, musical instruments, etc.

***Tabebuia heptaphylla* (Vell.) Tol. - *Bignoniaceae* (Ipê)**

It is found from the south of Bahia to Guanabara. *Tabebuia* is also common at the Atlantic forest of Rio de Janeiro and Guanabara, north of the Serra do Mar. The wood is difficult to saw, and it is used for heavy construction and outdoor structures, civil and naval, ship keels, bridges, sticks etc.

***Virola surinamensis* (Rol.) Warb. – *Myristicaceae* (Ucúuba)**

The tree species reaches a medium size with a height of 30 – 35 m and a diameter of 60 – 90 cm. The geographical distribution encloses Pará State, the east part of Amazonas State including the shallow Negro river, Roraima, the northeast of Brazil (from Maranhão to Pernambuco, possibly farther), Guinea, Venezuela, Trinidad, and some small West Indies. It also occurs in Peru, next to Iquitos.

Material and methods

At the experimental field of EMBRAPA Amazônia Ocidental (Manaus-AM), agroforestry test plots were installed in 1992 and 1993 on abandoned and/ or degraded areas, with the objective to know the behaviour of twenty forest tree species in different systems of plantation (monoculture, mixed culture and enrichment culture).

In January 1995, a scientific cooperation of Brazil and Germany, within the „SHIFT“-programme initiated an investigation of the growth of eight timber species of great commercial value. The species *Carapa guianensis* Aubl., *Cedrela odorata* L., *Ceiba pentandra* (L.) Gaertn., *Dipteryx odorata* (Aubl.) Willd., *Hymenaea courbaril* L. var *courbaril*, *Swietenia macrophylla* King, *Tabebuia heptaphylla* (Vell.) Tol., and *Virola surinamensis* (Rol.) Warb.) were selected from three different culture systems: **System 1** – Monoculture, *S. macrophylla*, *C. guianensis*, *C. odorata*, *D. odorata*, *H. courbaril*, *C. pentandra*, *V. surinamensis*, *T. heptaphylla*, **System 2** – Mixed agroforestry system, *S. macrophylla*, *C. guianensis*, and **System 3** – Enrichment in 25-year-old „capoeira“ lines, *S. macrophylla*, *C. guianensis*, *C. odorata*, *D. odorata*, *H. courbaril*.

The tests in plenty sun or in enrichment cultures at the „capoeira“ were installed in January 1992, located at km 24 of the highway that connects Manaus and Itacoatiara, Amazonas State. The geographic coordinates are 3°8' latitude south, 59°52' longitude west and 50 m above sea level.

The local climate is classified as Afi, by Köppen's system. Based on the observations made in the period from 1984 to 1993, the annual average of precipitation approximately is 2.656 mm. The annual average temperature is 25.7°C. The relief is flat and the soil is classified as a yellow latosol with a clay texture. The soil chemical characteristics at the initial stage of the plantation are shown in table 1.

Table 1: Soil chemical characteristics in the different experimental areas.

Test	Depth (cm)	PH (H ₂ O)	N (%)	P	K	Ca	Mg	Al
				Ppm		Meq		
Plenty sun	(0 – 20)	4.3	0.17	1.0	20.0	0.26	0.11	1.70
Enrichment lines	(0 – 20)	4.4	0.17	1.0	30.0	0.39	0.21	1.80

For the tests realized in plenty sun, the experimental area previously was covered with primary equatorial forest, followed by a plantation of *Hevea brasiliensis* (rubber tree) and *Pueraria phaseoloides* as soil cover. In 1989, the rubber trees, then 20 years old, were felled, leaving only the *Pueraria* in the area. The tree species were planted in plots of 225 m² with 25 plants, spaced in 3.0 m x 3.0 m, complete randomized plots design, with four repetitions, being evaluated by the nine individuals in the centre.

The enrichment line test was installed in „capoeira“ with approximately 25-year-old trees. At this plantation, a variety of species was registered, composed of 76 genera and 39 families. The species were planted in linear plots with 10 plants/ species, spaced at 3.5 m among the plants and 7.0 m between lines, in a completely randomized plot design, with four repetitions, being evaluated in its totality. The culture lines were opened at the east-west direction, with a width of 3.0 m.

In the two tests, fertilization was applied at the time of planting, equivalent to approximately 10 grams of phosphorus per plant.

In the mixed culture, it was used a complete randomized blocks design, with five repetitions. It includes 12 trees of *Hevea brasiliensis* spaced at 8.0 x 20.0 m, four of *Schizolobium amazonicum*, spaced at 12.0 m x 20.0 m, four of *S. macrophylla*, and four of *C. guianensis* spaced of 7.0 m x 20.0 m. The secondary vegetation settled between the lines of the culture (*Vismia guianensis* and *Vismia japonensis*). The fertilization plan is described in table 2.

The determination of survival percentages (SUR), height (H), diameter at breast height (DBH) and the attacks of weeds and disease were carried out in one-year-intervals. For the measurement of tree height, the Haga hipsometer was used, and the twig was graded of 5.0 m with the precision in centimetres. A diametric tape with precision in millimetres was used to measure diameters.

Table 2: Fertilization plan in grams/ plant (g/ pl) for the forest species

Product	Fertilization (g/ pl)					
	GRAVE – FEV/ 93		COVER – MAR/ 93		COVER – DEZ/ 93	
	100% ¹	30% ²	100%	30%	100%	30%
Lime	500	150	----	----	----	----
Urea ¹	----	----	65	20	50	15
SFT	155	47	----	----	100	30
KCL	100	30	----	----	50	15
MgSO ₄	----	----	----	----	50	15
FTE BR8	----	----	----	----	20	6

¹ 100% fertilization recommended in literature

² 30% fertilization recommended in literature

The seeds of the native species were collected in Manaus-AM and Santarém-PA. The seeds of *Tabebuia heptaphylla* were from São Paulo. The seeds were put in polyethylene bags at the nursery of the EMBRAPA. After a period of 4 – 6 months, they were planted in the field. Further site characteristics with regard to the water and element supply of the trees are described by DÜNISCH et al. (1999a) and DÜNISCH et al. (1999 c).

The characteristics described are according to BAUCH and DÜNISCH (1996). In all culture systems, the water availability is higher at the superior surface of the soil (0 – 20 cm). The field capacity in the systems 2 and 3 is larger in all the soil depths, compared to system 1, which indicates serious water problems to planted species in the system 1 during the dry period.

Results and discussion

Several abiotic and biotic factors influenced the behaviour and the growth of the selected forest species. In particular, climate, soil, fertilization, competition, weeds and diseases are of importance at the experimental areas.

Hypsipyla grandella frequently attacks the species of *Meliaceae*, which has a negative influence on the growth and survival rates of these species. It can be concluded from Fig. 1 that in particular *Swietenia macrophylla* was heavily attacked, which was expressed by a percentage of survival in system 1 of 50%, of 45% in system 2, and of only 20% in system 3 after five years. Moreover, also the growth rate of *Swietenia* in system 3 is very much restricted. Although *Carapa* also suffers from *Hypsipyla* attacks, the rate of survival in all three systems is higher than 85%. Similar values were obtained for *Cedrela*. The other species correspond to *Cedrela* in their rate of survival.

In general, the average increments in height, DBH and basal area, were significantly larger in system 1, compared to system 2 and 3 (Table 3). This can be explained to a great extent with some site characteristics already described, such as low competition among the species, higher element concentrations in the trees, and the soil cover (*Pueraria* and *Homolepis*) that had positive influence on the K supply in system 1.

The average values in height, obtained for all species (Table 3), shows the general tendency of intensified growth with the conditions of monoculture. Also the average values of DBH in monoculture conditions was superior, when compared to systems 2 and 3. The wood volume at the three systems (Figure 2) showed great differences among the plantation systems, due to the survival index and the differences of spaces used.

The results of the average stem volume (Fig. 2) for *Ceiba* in system 1 with 0.27m³ after five years of growth is most striking. Considering the low wood density of this species, the stem biomass production per tree reaches the maximum value of all species tested. Calculating the value of the stem biomass, as well, leads to favourable results for the growth of the other species under the conditions of system 1. After five years, *Carapa* exhibits 0.064 m³, *Cedro* 0.100 m³, *Dipteryx* 0.024 m³ (a very heavy and durable species), *Hymenaea* 0.098 m³, *Swietenia* 0.053 m³, *Tabebuia* 0.040 m³ and *Virola* 0.043 m³. The growth of *Carapa* and

Swietenia under mixed culture conditions (system 2) is only about half, compared to system 1, and the enrichment system does only allow reduced growth rates for all five species examined. The results, described by BAUCH and DÜNISCH (1996) and DÜNISCH et al. (1999b) on the growth dynamics for the period from April 1995 to March 1997, showed large increments for *Ceiba* and *Hymenaea*. There is no cambial cell division of *C. odorata* and *T. pentaphylla* during the dry season, indicating a strong influence of water supply on the cambial activity of these species. The rates of cellular division of *H. courbaril* and *C. pentandra* were reduced during the dry period (August/ September and September/ October, respectively). *D. odorata* showed little seasonal variation in the rate of cellular division. *S. macrophylla*, *C. pentandra*, and *V. surinamensis* showed a high rate of cellular division during the period from May to June 1995.

The same authors, comparing the dynamics of growth among the plantation systems, concluded that the tree growth is also strongly influenced by genetic factors. A typical growth pattern was detected for *C. odorata*, *D. odorata* and *H. courbaril* in monoculture conditions and enrichment cultures. It was also observed a high biomass production of *C. guianensis* at the plantation systems 2 and 3. This indicates less susceptibility to competition, when compared to the other species.

C. guianensis turned out to be more competitive than other species. *Carapa*, occurring abundantly at the plain forest of Amazonas and Pará, and on the terra firme, is a species of great commercial interest due to the wide range in use of its wood in construction and carpentry. This species occupies a leadership position among the exported wood of Amazonian-like, the most important medical plants of the region (LOUREIRO et al., 1979).

Table 3: Height, average increment (DBH) and basal area (BA) per tree at an age of four years under the conditions of three plantation systems. In addition, average growth (height, increment, basal area) per year is listed.

SYS: System 1 (monoculture), system 2 (mixed culture), system 3 (enrichment culture).

AGE (years)	SPECIES	SYS	SPACING (m)	HEIGHT (m)	DBH (cm)	BA (dm ²)	HEIGHT (m/ year)	DBH (cm/ year)	BA (dm ² / year)
4.0	<i>Carapa</i>	1	3.0 x 3.0	4.97	9.8	0.7745	1.24	2.5	0.1936
4.0	<i>Cedro</i>	1	3.0 x 3.0	6.43	10.9	0.9199	1.61	2.7	0.2300
4.0	<i>Dipteryx</i>	1	3.0 x 3.0	6.02	4.7	0.2092	1.51	1.2	0.0523
4.0	<i>Hymenaea</i>	1	3.0 x 3.0	7.36	8.2	0.5805	1.84	2.1	0.1451
4.0	<i>Swietenia</i>	1	3.0 x 3.0	5.29	8.4	0.5868	0.99	2.1	0.1467
4.0	<i>Ceiba</i>	1	3.0 x 3.0	8.59	17.2	2.3579	2.15	4.3	0.5895
4.0	<i>Tabebuia</i>	1	3.0 x 3.0	4.19	6.6	0.5207	1.05	1.6	0.1302
4.0	<i>Virola</i>	1	3.0 x 3.0	4.54	6.5	0.3239	1.14	1.6	0.0810
4.0	<i>Carapa</i>	2	7.0 x 20.0	5.46	8.3	0.5611	1.37	2.1	0.1403
4.0	<i>Swietenia</i>	2	7.0 x 20.0	5.84	7.4	0.4311	0.88	1.8	0.1078
4.0	<i>Carapa</i>	3	3.5 x 7.0	4.36	4.9	0.2024	1.09	1.2	0.0506
4.0	<i>Cedro</i>	3	3.5 x 7.0	3.67	4.0	0.1244	0.92	1.0	0.0311
4.0	<i>Dipteryx</i>	3	3.5 x 7.0	3.23	2.0	0.0374	0.81	0.5	0.0093
4.0	<i>Hymenaea</i>	3	3.5 x 7.0	2.67	1.8	0.0283	0.67	0.5	0.0071
4.0	<i>Swietenia</i>	3	3.5 x 7.0	2.83	2.7	0.1074	0.71	0.7	0.0268

At the Ducke Reserve of INPA, in an experiment with lateral shadow of approximately 20% with four-year-old plants, *Swietenia* presented survival rates of 54% with 2.08 m height and 1.4 cm diameter (DBH) in the spacement of 5.0 m x 2.5 m (LOUREIRO et al., 1979).

This species is frequently attacked by a larva of a moth (*Hypsipyla grandella*), in the nursery phase and under field condition. The larva generally attacks the apical shoot, causing the loss of apical domination. As a result, there is a formation of many secondary shoots besides a delay in the height growth, which can cause the death of the plant.

In the Amazon, the species *Swietenia* has been tested with some success, in plantations with agricultural system management and with other forest species. At these conditions, the attack is minimized, not causing serious damage to the plant development (BRIENZA, jr., 1983; SOUZA, 1996).

The attack of *H. grandella* was first observed, in system 1. Although, due to the proximity of the experimental plots, the caterpillar (*H. grandella*) quickly manifested itself in the shadow environment. Presently, 100% of the plants of *Swietenia* are attacked, regardless of the vegetation system and the species protection. The stem in the majority of the trees is badly formed and consequently of reduced commercial value.

Although *Swietenia* is a potential species for the culture in humid tropical regions, it cannot be recommended to be planted under the selected conditions. This species has to be planted under partial shadow conditions or selected for polycultural systems with other forest species. Fast-growing tree species can be offered as a protection against the attack of *H. grandella*.

Swietenia is the most promising for its growth in diameter and height, it is moderately resistant to the "broca dos ponteiros" attack and for a good rate of survival in the systems 1, 2, and 3, respectively. Besides, the species can be planted in association with other forest species and under agricultural conditions. At the Ducke Reserve, Manaus, it develops well at plenty sun (100% of light), presenting a survival of 98% at an age of nine years with 6.24 m height, and 7.3 cm DBH (LOUREIRO et al., 1979).

In partial shadow, it was observed an average growth in diameter, always inferior to the condition of monoculture (Table 3). According to VOLPATO et al. (1972) and LOUREIRO et al. (1979), it is commonly observed that in partial shadow *Carapa* plants lose in diameter to win in height. Up to the present, such facts could not be verified. In monoculture, the annual diameter increment can reach 1.91 cm/ year with seven-year-old plants (YARED et al., 1988; VOLPATO et al., 1972). ALENCAR and ARAÚJO (1980), also indicated higher growth-rates in partial shadow related to the height.

The figures on the growth of *Cedro* in distinct situations indicate a great variety. The differences in height and diameter growth were significant among the vegetation systems 1 and 3 (Table 3). At the age of five years, the annual increment oscillated between 1.48 m/ year to 0.97 m/ year and in diameter 2.5 cm/ year to 0.9 cm/ year.

The species *H. courbaril*, *V. surinamensis*, and *C. pentandra* are promising by the performance presented in the monoculture. *H. courbaril* showed excellent survival rates: 100% in the culture in open area and around 80% in partial shadow. However, the height and diameter growth in partial shadow is inferior compared to the culture in open area (Table 3), showing the non-adaptability of the species to this kind of site. In open area, *V. surinamensis* showed an excellent survival (90%), fast growth and good shape. The growth in height and diameter was good (Table 3). *C. pentandra* presented an excellent growth, and a necessity for planting it in wider space already became obvious.

Other species that potentially can be used in reforestation and that have presented an acceptable growth and a good shape are *T. pentaphylla* and *D. odorata*.

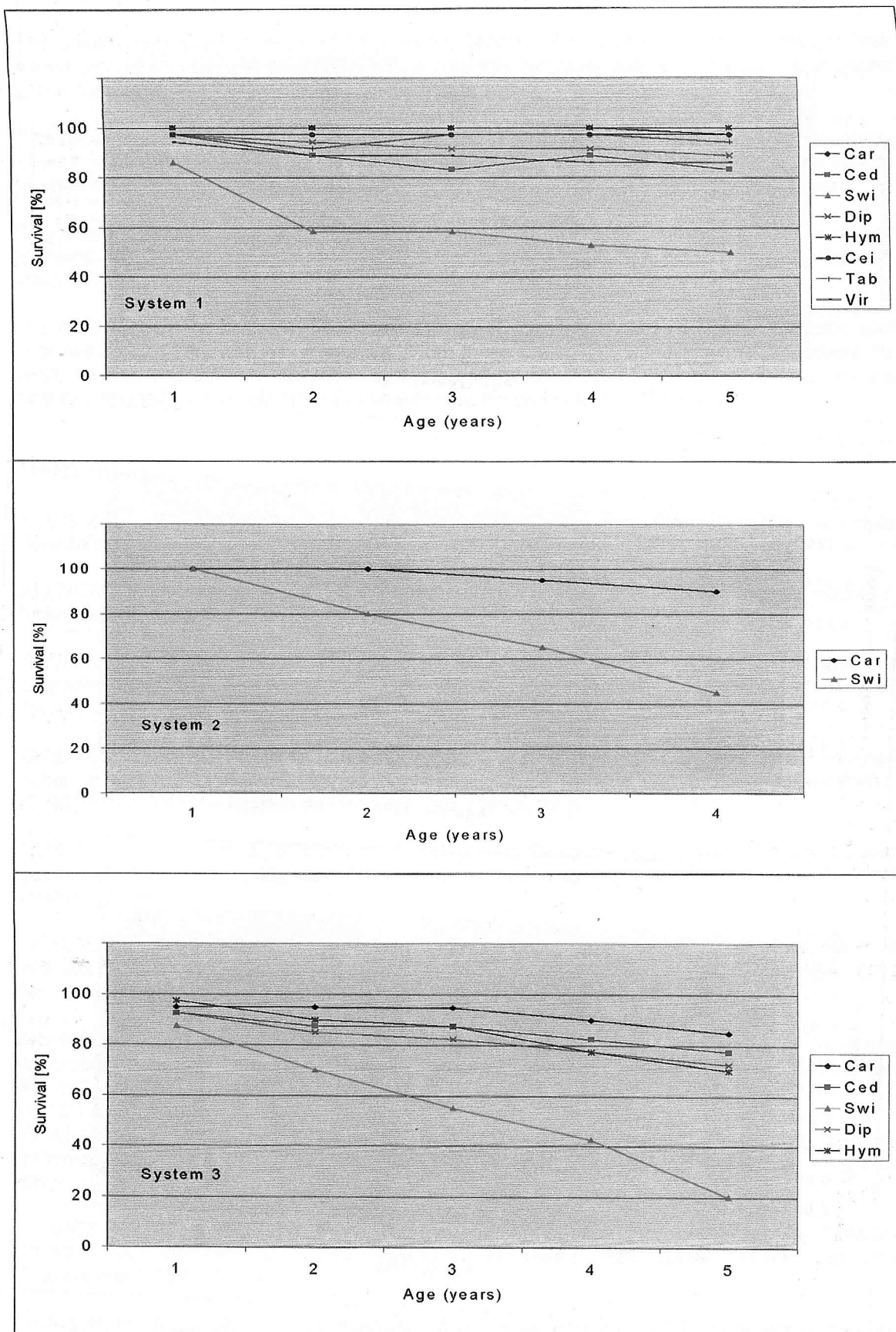


Fig. 1: Percentage of survival [%] of the planted tree species of the three systems. System 1 (monoculture), system 2 (mixed culture), system 3 (enrichment culture). Car = *Carapa*, Ced = *Cedrela*, Cei = *Ceiba*, Dip = *Dipteryx*, Hym = *Hymenaea*, Swi = *Swietenia*, Tab = *Tabebuia*, Vir = *Virola*

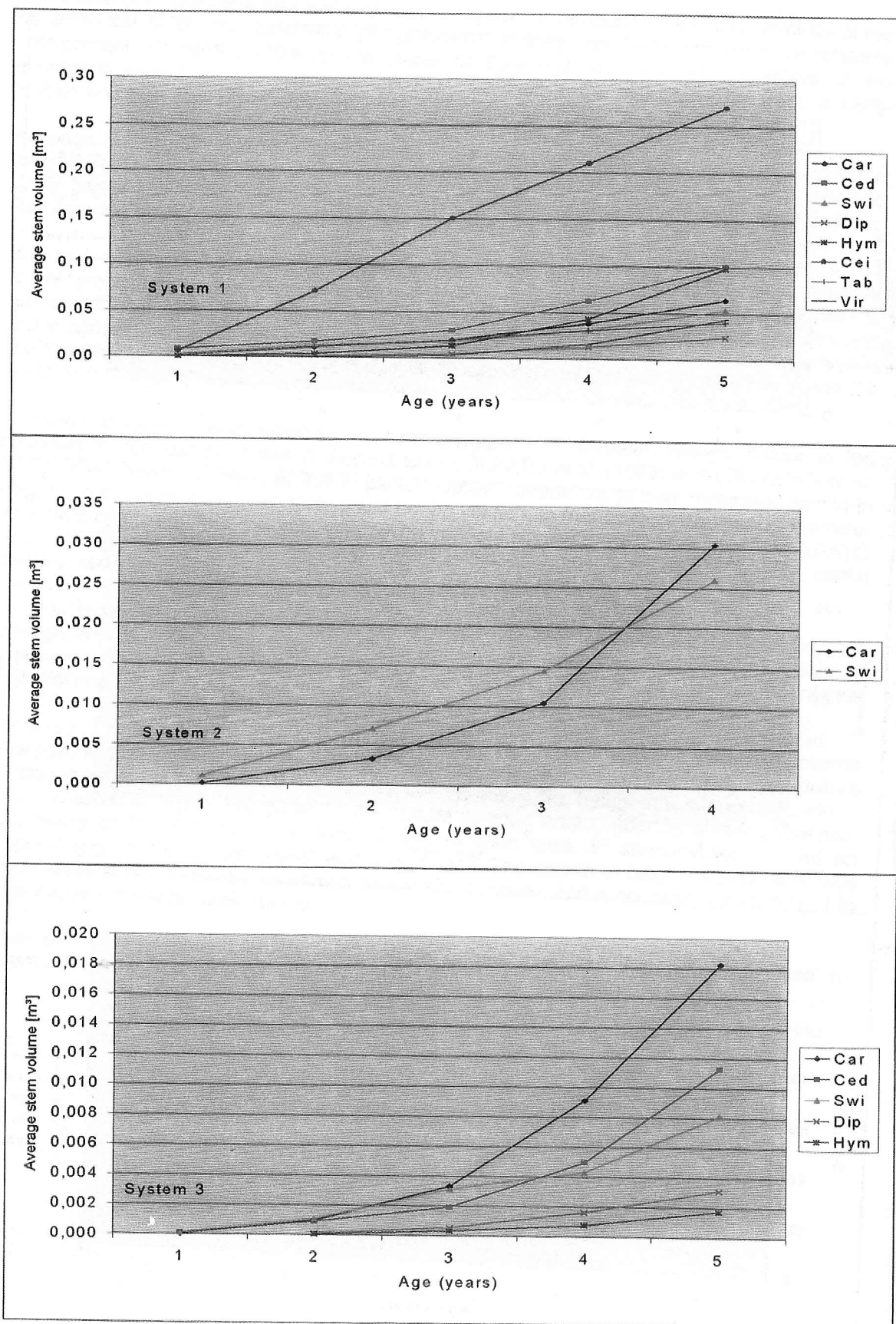


Fig. 2: Average volume of the stem [m³] per tree species of the three plant systems System 1 (monoculture), system 2 (mixed culture), system 3 (enrichment culture) Car = *Carapa*, Ced = *Cedrela*, Cei = *Ceiba*, Dip = *Dipteryx*, Hym = *Hymenaea*, Swi = *Swietenia*, Tab = *Tabebuia*, Vir = *Virola*

Conclusion

The growth expressed in terms of total height, breast height diameter, and volume per tree varied among species and among the culture systems, which suggests a very careful selection of the species to be planted in a specific plantation system.

The most promising culture system, according to growth results, is system 1 (monoculture). *Carapa guianensis*, due to its ecological adaptation, is the most adaptable species to the culture in open area and on partial shadow, and is suitable as a component of agroforestry systems.

The attack of *Hypsipyla grandella*, on the *Meliaceae* species, was noted in all of the culture systems. It negatively influenced the growth in height and caused mortality, especially for *S. macrophylla*.

It is necessary to emphasize that the results presented are only based on one seed source, and that results can vary with other sources. From these preliminary investigations carried out for eight species and different plantation systems can be concluded that provenance studies are urgently needed for the selection of optimally adapted seeds for the Manaus region.

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