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The development of cupuaçu plants (*Theobroma grandiflorum* Willd. ex Spreng. Schum.) in different mixed cultivation systems and the effect of topographic features

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ABSTRACT

The development of 750 cupuaçu plants has been monitored after 3½ and 4½ years of growth in three different mixed cultivation systems and one monoculture. It has been found that the plant development vary significantly between the planting systems, the monoculture providing the worst conditions for the rapid maturation of cupuaçu plants. Additionally it could be ascertained, that the development of cupuaçu plants is significantly affected by the distance to the adjacent primary or secondary forest. The strength of this influence lies in the range of the tendency obtained by different levels of fertilization (30 % and 100 % of recommended dose). Other tested parameters (inoculation with VA-mycorrhiza fungi, topography in terms of slope and altitude) are not correlated with the development of cupuaçu plants, excepting an evident edaphic influence, which becomes perceptible between the three western repetition blocks of the experiment and the two eastern blocks. Possible factors leading to the observed variability of plant development are discussed.

RESUMO

Avaliaram-se o desenvolvimento do 750 cupuaçuceiros após 3,5 e 4,5 anos crescimento em três sistemas policultivos e um sistema monocultivo. Foram verificadas diferenças significativas entre esses sistemas, o monocultivo se relevando como o sistema menos vantajoso para uma maturação acelerada das plantas. Sobre isso existe uma relação evidente entre o desenvolvimento dos cupuaçuceiros e cuja distancia á mata primária ou secundária, quais cercam o campo experimental. A intensidade desta influencia sobre o desenvolvimento das plantas é comparável com a tendência causada pelos níveis diferentes de adubação (30 % e 100 % da adubação recomendada). Os demais parâmetros (inoculação com fungos micorrhiza-VA, topografia em termos do declive e da altitude) não estão relacionados com o desenvolvimento dos cupuaçuceiros. Porém foi observado uma diferença evidente entre os três blocos repetitivas no oeste do campo experimental e os dois no leste, qual provavelmente se baseia em fatores edáficos. Explicações possíveis para a variabilidade do desenvolvimento são discutidas.

ZUSAMMENFASSUNG

Untersucht wurde die Entwicklung von insgesamt 750 Cupuaçu-Pflanzen nach 3½ und 4½ Jahren Kultur in drei Polykulturen und einer Monokultur. Es ergaben sich signifikante

Unterschiede zwischen den Pflanzsystemen, wobei die Monokultur die ungünstigsten Bedingungen für das Heranreifen der Pflanzen zeigte. Darüber hinaus besteht zwischen der Entwicklung der Pflanzen und deren Entfernung vom benachbarten Primär- oder Sekundärwald ein deutlicher Zusammenhang, dessen Stärke vergleichbar ist mit der Tendenz, die durch verschiedene Düngergaben erzielt wurde (30 % und 100 % der empfohlenen Düngermenge). Die übrigen untersuchten Parameter (Inokulierung mit VA-Mykorrhiza-Pilzen, Geländeeigenschaften gemessen als Gefälle und Höhenlage) konnten nicht mit der Pflanzenentwicklung korreliert werden, abgesehen von einem signifikanten, vermutlich edaphisch begründeten Unterschied zwischen den drei westlichen und den zwei östlichen Wiederholungsblöcken des Feldexperimentes. Mögliche Erklärungen für die Variabilität der Pflanzenentwicklung werden diskutiert.

INTRODUCTION

The cupuaçu tree, *Theobroma grandiflorum* (Willd. ex Spreng.) Schum., is native in the South-East of Pará, Brazil, where it represents a constituent of the medium stratum of the terra-firme rain forest. Its considerably big fruits (1-2 kg fresh weight) consist of a lignified husk encasing 20-45 seeds which are surrounded by a very aromatic pulp, which constitutes about 35-45 % of the fruit's fresh weight. The cupuaçu tree can be found throughout the Amazon basin as part of spontaneous vegetation on non-inundated areas, particularly near existing or former settlements (Ducke 1953, Venturieri 1993). The high market value of the fruit pulp (2 - 4 US$ per kg), which is used for the production of juice, ice-cream, yogurts, and other fresh products, makes the cultivation of cupuaçu-trees more and more attractive (Laker and Trevisan 1992). Furthermore the close relationship to the cocoa-tree (*Theobroma cacao* L.) gives rise to the presumption that in addition to pulp production the seeds of *T. grandiflorum* (ca. 20 % of fresh weight) could be used for manufacturing chocolate-like foodstuffs. This additional use option would reveal the advantage of producing a storable ware which would supply a separate market. However, attempts to commercialize a type of chocolate-wares made from cupuaçu-seeds failed so far, probably due to the unsatisfactory and hardly reproducible quality of the product. Studies dealing with seed inherent factors determining the aroma potential of *T. grandiflorum* are recently conducted in collaboration of the EMBRAPA Amazônia Ocidental, Manaus, and the Institute of Applied Botany, Hamburg, within the frame of the project.

The expanding cultivation of *T. grandiflorum* is guided by breeding programs evaluating agronomic characteristics of strains and clones of primary selected plant material (de Souza et al. 1992a, 1992b, Guimaraes et al. 1992, de Souza and de Santos, 1996). In addition to these efforts, which mainly focus production parameters under standard conditions, it is necessary to investigate, to which extent varying site specific factors, as given by different cultivation systems and topographic conditions, influence the development and productivity of cupuaçu plants, in order to line out a type of agro-ecological profile, and to identify the most advantageous conditions for its cultivation (Hunter 1990, Reisdorff et.al. 1997).

MATERIAL AND METHODS

750 seed derived cupuaçu plants are cultivated as part of a recultivation experiment of a 19 ha fallow rubber plantation on a former terra firme rain-forest area near Manaus (Feldmann et al. 1995). In 1993 after slashing and burning of the fallow area the cupuaçu seedlings have been planted in three mixed cultivation systems and one monocultural system in plots of 48m x 32m (see Figure 1 and Table 1). Four variants of treatment have been conducted in each mixed cultivation system: inoculation (with or without) of the seedlings with vesicular-arbuscular mycorrhiza fungus, and application of 100 % or 30 % of recommended fertilization. The monoculture has been managed according to conventional practice as recommended by agronomists. The entire recultivation experiment is conducted in five repetition blocks covering an area of ca. 1200 m length (North-West to South-East) and a maximum width of ca. 160 m.

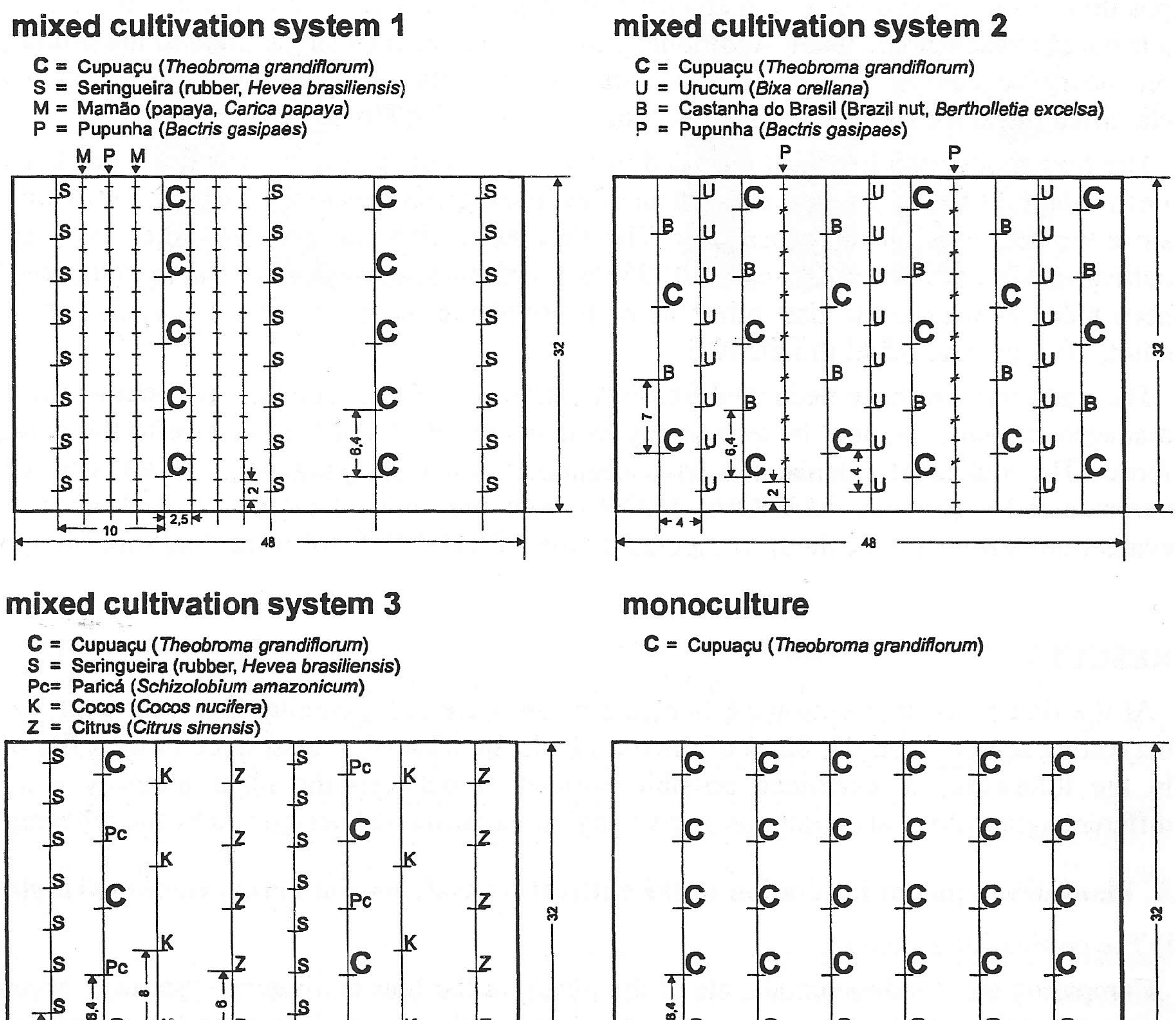

Figure 1: Plantation plans of the four tested cultivation systems

Table 1: Species directly neighbored to cupuaçu *(Theobroma grandiflorum)* in the four cultivation systems and spacing between and within the rows

Cultivation system	neighboring species within the row	spacing within the row	species of next row	spacing to next row
mixed system 1	*Theobroma grandiflorum*	6.4 m	*Carica papaya* [1)] *Bactris gasipaes*	2.5 m 5 m
mixed system 2	*Bertholletia excelsa*	6.4 m	*Bixa orellana* *Bactris gasipaes*	4 m 4 m
mixed system 3	*Schizolobium amazonicum*	6.4 m	*Hevea brasiliensis* *Cocos nucifera*	5 m 5 m
Monoculture	*Theobroma grandiflorum*	6.4 m	*Theobroma grandiflorum*	7 m

[1)] Carica papaya has been taken out from system 1 in 1996

Each cupuaçu plant has been registered with regard to the topography of its particular position in the field: after a ground-survey in steps of 25 cm the altitude and the slope has attributed to each single plant. Additionally the distance of each single plant to the primary or secondary vegetation, which surrounds the experimental site, has been documented and classified (distance less than 15 m, 15-30 m, 30-45 m, 45-60 m, more than 60 m).

The fruit production has been recorded in terms of number of harvested fruits per tree and fresh weight of fruits. The respective data of every single cupuaçu plant have been monitored since the beginning of the experiment. The first production was observed after 3½ years of cultivation in the harvesting season 1995/96 (November - May). The fruit production has been taken as measure to determine the maturity of the plants (no fruits: juvenile; fruiting: adult; 10 fruits and more: productive).

The maturity data have been analyzed in relation to the four cultivation systems, the four management variants, and the topography in terms of relief and the distance to the adjacent forest. The statistical calculations have been performed applying multivariate analysis of variance and covariance (MANOVA/MANCOVA) and multiple regression analysis (for the evaluation of topographic data), computed by the STATISTICA-software (StatSoft, Inc.).

RESULTS

At the first harvesting season 54 % of the plants were still juvenile. One year later, in the harvesting season 1996/97, 82 % of the trees had fructificated at least once in their life time. In the following we examined possible correlation between the plant maturity and the different agroecological conditions as given by the experimental design and by the topography.

A. Plant development in relation to the cultivation systems and management variants

i) The cultivation systems

Comparing the developmental state of the plants in the four cultivation systems it becomes evident that the tested mixed cropping systems obviously provide better conditions for a rapid development of cupuaçu trees towards fruit production than the monoculture (Figure 2). Especially system 1 is prominent regarding its high percentage of adult plants even in the first harvesting season (81.5 % adult plants in 1995/96). Additionally, plants with exceptionally high yields (more than 15 fruits per tree) were only found in system 1 during the harvesting season 95/96. After 4½ years nearly all plants are adult in system 1 and in system 2 as well. At this time the inferiority of system 3 becomes evident (still 31 % juvenile plants in 1996/97). In the monoculture, which was designed and handled according to common practices, only 16 % of the plants were adult in the harvesting season 1995/96, and one year later the majority of the plants (55 %) did not yet enter the state of fructification.

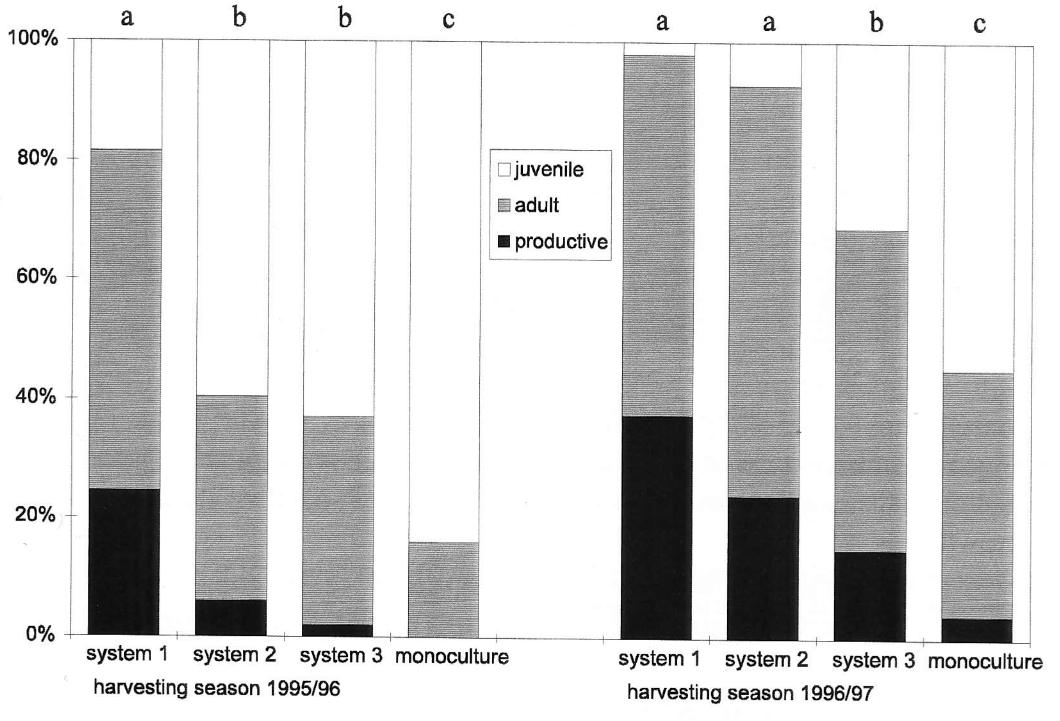

Figure 2: Percentage of juvenile, adult, and productive cupuaçu trees after 3½ and 4½ years of cultivation in different cropping systems.

Different letters (at the top of the columns) indicate significant differences at an error probability of p < 0,01 (Tukey honest significant difference test for unequal N)

ii) The management variants

Comparing the variants of management measures in the harvesting season 1995/96 - fertilization levels and inoculation with vesicular arbuscular mycorrhiza fungus - no significant differences could be observed, if the multivariate analysis of variance (MANOVA) is conducted using the mean values of treatment plots as data set. However, following the multiple regression analysis using the primary data (development of each single plant) a positive influence of fertilization on plant development becomes statistically significant at a $p < 0{,}01$ (for details of the multiple regression approach see B. Plant development in relation to the topography).

These results corroborate, that the development pattern of cupuaçu plants towards maturity mainly depends on the cultivation systems, the monoculture and system 3 providing obviously worse conditions than the systems 1 and 2. According to the analysis of variance neither the inoculation with mycorrhiza fungi nor the different fertilization quantities (30 % and 100 % of recommended fertilization) did cause statistically valid differences considering the development of cupuaçu plants. However, a certain positive influence of fertilization was observed if analyzing the primary data by the multiple regression method.

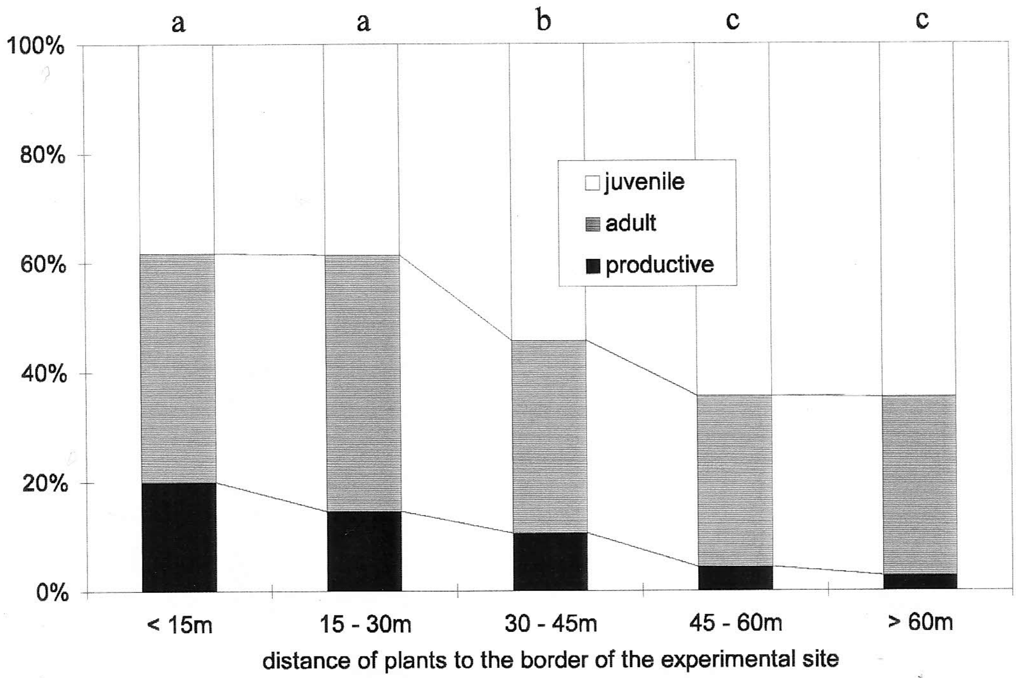

Figure 3: Percentage of juvenile, adult, and productive cupuaçu trees in different distances to the border of the experimental site after 3½ years of growth.
Different letters indicate significant differences at an error probability of $p < 0,01$ (Tukey honest significant difference test for unequal N)

B. Plant development in relation to the topography

i) Differences between the repetition blocks

The 5 repetition blocks of the 19 ha experimental site have been set up in a line covering an area of ca. 1200 m length (north-west to south east) and a maximum width of ca. 160 m. Significant differences in the plant development became very evident between the three north-western blocks (blocks A, B, and C) and the two south eastern blocks (blocks D and E). E.g. in block E only 17 % of the cupuaçu trees had reached the reproductive stage after 3½ years of growth, whereas in block C 90 % of the plants had already been producing fruits. The unexpectedly blunt differences of the plants' development between the blocks are probably caused by edaphic factors which have not yet been specified.

ii) The distance to the primary and secondary forest

The experimental site is surrounded by primary and secondary forest. In the first harvesting period (after 3½ years of growth) we observed a considerable influence of the plants' distance to the border of the experimental site on production and development, which is statistically corroborated (Tukey's honest significant difference test for unequal N). The developmental state of cupuaçu plants was advanced near the border of the experimental site (62 % adult trees). The amount of adult plants decreased towards the central part of the field (45 % adult trees). The difference of plant development between the border and the central part of the field becomes even more evident, if the plants of advanced development (plants bearing 10 and more fruits) are taken into account separately: 20 % of the plants near the border already produced considerably, whereas only 3 % of the plants in the field's center arrived at this advanced state of development (see Figure 3). At the harvesting period 1996/97 this tendency - advanced development near the field's border - is still observable in the system 3 and slightly in the system 2. Thus, it seems to be reasonable to assume a certain type of influence of the adjacent primary and secondary forest on the development of cupuaçu plants (see discussion), which is perceptible up to a distance at about 45 m.

iii) The relief

Features of the relief have been attributed to each single cupuaçu plant in terms of slope and altitude of its position, the slope ranging from 0 to 25 cm/m, the altitude from 40 to 50 m above sea-level. The relationship between the plant maturity and the topographic features have been analyzed by the multiple regression method. All other recorded parameters (cultivation systems, fertilization, mycorrhiza inoculation, repetition blocks, distance to the border of the field) have been included in the computation thus coming to partial correlation, the respective variable being controlled for all other variables. In Table 2 the results of the multiple regression analysis are summarized in terms of the standardized regression coefficients (beta), the squared semi-partial correlation coefficient (R_{sp}^2), and the level of significance (p-level). The magnitude of the beta value allows to compare the relative contribution of each recorded parameter in the prediction of the dependent variable (plant development), the R_{sp}^2 is an indicator of the percent of total variance uniquely accounted for by the respective parameter, and the p-level represents the probability that the found relation is a "fluke".

According to the results of the multiple regression analysis about 30 % of the total variability of plant development can be explained by the recorded parameters, the cultivation systems being the most decisive factor, followed by the different edaphic conditions given by the repetition blocks. It is remarkable that the strength of influence due to fertilization is comparable to the effect of the distance of plants to the border of the experimental site, thus, suggesting that the influence of the adjacent forest is unexpectedly intense. The topographic features, the altitude and especially the slope, can be considered to be not that evident for the plant development.

Table 2: Summarized results of multiple regression analysis of the development of cupuaçu plants within 3½ years of cultivation.

parameter (independent variable)	beta	R_{sp}^2	p-level
cultivation system	0.490	0.1933	< 0.001
repetition block	0.291	0.0544	< 0.001
fertilization	0.176	0.0270	< 0.001
distance from the border	- 0.162	0.0241	< 0.001
altitude	- 0.095	0.0051	0.012
mycorrhiza inoculation	0.051	0.0022	0.101
slope	- 0.019	0.0002	0.599

The parameters are listed in order of strength of influence. beta: standardized regression coefficients; R_{sp}^2: squared semi-partial correlation coefficient; p-level: level of significance (see text for explanations)

Are these tendencies consistently observable in each cultivation system?

In system 1 the developmental state of the plants after 3½ years (1996) is correlated with the block (different edaphic conditions), whereas the other factors did not have a significant effect (see Table 3). In 1997 neither the block-effect nor any other factor could be evidently correlated to the developmental state of the plants in system 1. This give rise to the assumption that system 1 seems to be capable to stabilize itself in that way, that, considering the development of cupuaçu plants, the strong edaphic influences are minimized in the first 4½ years of cultivation. Further on, the other factors did not influence the plant development in system 1 as they did in the systems 2 and 3 (see below).

In system 2 the block-effect is very strong in 1996 and still observable in 1997. The distance to the field's border is significantly correlated with the plant development in 1996, even stronger than the fertilization, which seems to have a certain effect in system 2. One year later the distance and the block-effect remain a significant influence, but less evident. This could be interpreted in that way, that the positive influence of the adjacent forest is very evident in system 2 in the first 3½ years, while the respective conditioning factors are developed within the system itself in the course of the next year. This would mean that the self-stabilization potential of system 2 is retarded compared to system 1.

In system 3, the "worst" system of the poly-cultures considering the development of cupuaçu, the block-effect is obvious in 1996. While the edaphic differences between the blocks do not remain effective in 1997, the distance-effect becomes very evident. This could mean that the factors emanating from the adjacent forest become visible later in system 3, which is the most retarded mixed system considering the development of cupuaçu.

Table 3: Relative strength of factors influencing the development of cupuaçu plants in different cultivation systems, according to multiple regression analysis.

parameter	system 1		system 2		system 3	
year	1996	1997	1996	1997	1996	1997
repetition block	0,23	n.s.	0,46	0,21	0,29	n.s.
fertilization	n.s.	n.s.	0,22	n.s.	n.s.	0,27
distance to the border	n.s.	n.s.	- 0,38	- 0,29	n.s.	- 0,59

Presented are the significant standardized regression coefficients at $p < 0,05$ (beta-values); n.s. = no significance. The respective significance levels are corroborated by MANOVA (data not shown).

DISCUSSION

What are the factors leading to the observed considerable differences in the development of cupuaçu plants? In the case of the comparison of the cultivation systems the first approach is to estimate, whether the observed features of plant development correspond with the system immanent characteristics, the most apparent being the species composition and the spacing between the rows (Table 1). However, it needs to be considered that the species composition marks only the initial point of complex interactions of biotic and abiotic factors. For instance one could imagine that certain circumstances favor the growth of one species which itself favors the growth of a certain neighbored plant species. The mode of this influence could be direct (e.g. shading) or indirect (e.g. by affecting the soil micro-fauna and -flora). A synergism of this type could lead to a more effective turnover of nutrients, because one would expect that the root growth and consequently the efficiency of nutrient uptake increases as well. This would be a very simplified aspect for the capacity of a cultivation system to stabilize itself, keeping in mind that the reality is more complex. The following attempts to identify possible causes for the observed heterogeneity of plant development must be considered as hypothetical approach, being a starting point for distinct investigations of the respective putative factors effecting the development dynamics of cupuaçu plants.

Until 1996, in the first 3½ years of growth, system 1 apparently provides the best conditions for the development of cupuaçu plants. Up to this time, the most obviously distinguishing feature of system 1 is the low distance to the next planting row consisting of *Carica papaya* (Table 1), which is characterized by a fast growth pattern and early productivity. It has been reported that during the first years a direct shading favors the development of cupuaçu plants (Venturieri 1993, Calzavara 1982, 1987). However, the low distance to *Carica papaya* did not lead to a direct shading of cupuaçu in the first 3½ years. Nevertheless the relatively high degree of coverage in system 1 could have led to more advantageous microclimatic conditions (humidity and temperature of soil and air). Additionally it should be taken into account, that the herbaceous soil cover, the creeping Fabaceae *Pueraria phaseoloides*, was best developed in system 1 in the course of the first 3½ years. This could have had consequences for the microclimatic conditions as well as for the nutrient balance: beside the general aspects of herbaceous soil protection it should be considered that on the one hand *Pueraria phaseoloides* lives in symbiosis with N_2-fixing *Rhizobium* bacteria, and that on the other hand as creeping plant it has the potential to shift nutrients laterally, which becomes interesting considering that the neighbored *Carica papaya* are supplied by relatively high doses of fertilizer (Schroth, personal communication).

In the course of 1996 the papaya plants have been taken out from the system 1. Thus, system 1 became more similar to system 2 considering the neighboring planting row (*Bactris gasipaes* , the peach palm, and *Bixa orellana* in system 2; *Bactris gasipaes* in system 1). It is remarkable that in the following harvesting period (1997) no significant differences of development of cupuaçu plants between system 1 and 2 could be observed any more; in both systems more than 90 % of the cupuaçu plants have been adult, while in system 3 and the monoculture 31 % and 55 % respectively of the plants were still juvenile. This observation could be a hint, that the advantageous conditions in system 1 considering the initial phase of plant development could be traced back to the close neighborhood of the papaya plants, while in a later phase of development the influence of the rapidly and high growing peach palms becomes more effective. Beside the presumable shading effect of the peach palms it is noteworthy that it has been ascertained that the quantity of litter-biomass under the peach palms is evidently higher than under cupuaçu plants (Schroth, personal communication). In this context it is imaginable that the creeping soil cover *Pueraria phaseoloides* contributes to the lateral distribution of nutrients being liberated from the litter of peach palm.

In system 3 the 5 m distant neighboring plant rows of cupuaçu consist of rubber trees and coconut trees. Due to the growth pattern and the habitus of the species (*Theobroma grandiflorum, Hevea brasiliensis, Cocos nucifera* and *Citrus sinensis;* see Table 1 and Figure 1) the physiognomy of system 3 appears quite more open, even in the fifth year of development. Consequently, the shading of cupuaçu plants as well as microclimatic effects are probably not that pronounced in system 3 as in the systems 1 and 2. Maybe these microclimatic conditions form the background which is finally leading to the worse development of the cupuaçu plants in system 3.

The monoculture significantly provides the worst conditions for the development of cupuaçu plants. The edaphic differences between the blocks are correlated with the plants' development in 1996, one year later none of the monitored parameters had an provable effect on the maturation of the plants in the monoculture. This possibly could be due to detrimental factors effective in the monoculture which are superimposing the influences which are observable in the mixed systems. For instance the soil cover within the monoculture mainly consists of grasses (e.g. *Homolepis aturensis*), which are presumed to be highly competitive for nutrients. It is not yet clear, to which extent the prevalence of Puerária in the mixed cropping systems is triggered by the higher amount of fertilizer applied per area. However, also in this case the quality of soil cover can be attributed to the planting systems since a higher dose of fertilizer per area is a consequence of a higher planting density which is enabled by mixing species of different growth patterns and habitus.

Considering the management measurements, an explicitly interesting fact is, that higher quantity of fertilizer (100 % compared to 30 % of the recommended dose) neither led to a significantly better development nor to improved productivity of the cupuaçu plants. However, the observed tendency due to fertilization is comparable to the (significant) effect of plant distance to the border of the experimental site. This implies the suggestion of a positive influence of the adjacent forest on the development of cupuaçu plants. This putative influence is not consistently observable in each cultivation system. In system 1 a slight tendency is perceptible, where in system 2 this is significant, and most pronounced in system 3. This order corresponds with the density of perennial crop plants in these mixed cropping systems (see Figure 1). Anticipating an influence of planting density on the micro-climate in the respective system, this observation indicates that putative factors emanating from the adjacent forest affect the micro-climate within the plantation, e.g. by shading, or by buffering climatic extremes. This effect is expected to occur especially during dry season via exchange of air masses. One could presume that system 1, which is characterized by the most dense vegetation, develops quite early a certain potential to stabilize micro-climatic conditions favoring the development of cupuaçu plants. This approach could explain the observation for system 1, where the distance of a cupuaçu plant to the adjacent forest barely influences its development. On the other hand, it seems to be a decisive factor for system 3. This hypothesis will be scrutinized by investigations of climatic parameters in narrow spatial dimensions during the next dry season.

REFERENCES

Calzavara, B.B.G., 1987: Cupuaçuzeiro. Recomendações Básicas, EMBRAPA, CPATU, 5 pp.

Calzavara, B.B.G., 1982: O Cupuaçuzeiro, *Theobroma grandiflorum*, SCHUM. Série: Cultivos Pioneiros, CPATU, Belém.

De Souza, A.D.G.C., Guimaraes, R.R., Nunes, C,D.M., 1992a: Avaliação preliminar de clones de cupuaçuzeiro (*Theobroma grandiflorum* (Willd ex Spreng) Schum), nas condições de Manaus, AM. I - Produtividade. Pesquisa em Andamento, EMBRAPA/CPAA, 11 , 1-6.

De Souza, A.D.G.C., Guimaraes, R.R., Nunes, C,D.M., 1992b: Melhoramento genetico do cupuaçuzeiro (*Theobroma grandiflorum* (Willd ex Spreng) Schum). Pesquisa em Andamento, CPAA/EMBRAPA, 12 , 1-4.

De Souza, A.D.G.C., Guimaraes, R.R., Nunes, C,D.M., 1992c: Avaliação preliminar de clones de cupuaçuzeiro (*Theobroma grandiflorum* (Willd ex Spreng) Schum), nas condições de Manaus, AM. II - Vigor da planta. Pesquisa em Andamento, EMBRAPA/CPAA, Manaus, Brasil, 13 , 1-5.

De Souza, A.D.G.C., de Santos, A.F., 1996: 1. Workshop sobre as culturas de *Cupuaçu* e *Pupunha* na Amazônia. Anais Manaus: EMBRAPA/CPAA 1996, Documento 6, 170pp.

Ducke, A., 1953: As espécies brasileiras do genero *Theobroma* L.. Boletim do Inst. Agrôn. Norte, 28 , 3-20.

Feldmann, F., Idzac, E., Martins, G., Nunes, J., Gasparotto, L., Preisinger, H., Moraes, V.H.F., Lieberei, R., 1995: Recultivation of degraded , fallow lying areas in central Amazonia with equilibrated polycultures: response of useful plants to inoculation with VA-mycorrhizal fungi. Angew. Bot., 69 , 111-118.

Guimaraes, R.R., De Souza, A.Das G.C., Nunes, C.D.M., 1992: Avaliação preliminar de clones de cupuaçuzeiro (*Theobroma grandiflorum* (Willd ex Spreng) Schum), nas condições de Manaus, AM. III - Caracteres físicos dos frutos. Pesquisa em Andamento, EMBRAPA/CPAA, 14 , 1-5.

Hunter, J.R., 1990: The status of Cocoa (*Theobroma cacao*, Sterculiaceae) in the Western Hemisphere. Economic Botany, 44 (4), 425-439.

Laker, H.A., Trevisan, O., 1992: The increasing importance of Cupuassu (*Theobroma grandiflorum*) in the Amazon region of Brazil. Cocoa Growers' Bulletin, 45 , 45-52.

Reisdorff, C., Lieberei, R., De Souza, A.G.C., 1997: Studies on the variability of cupuaçu plants (*Theobroma grandiflorum* (Willd. ex Spreng.) Schum.) growing in different cultivation systems on a degraded area: state of development and productivity of 3 1/2 years old trees. Proceedings of the 1. Conference on Fruit Production in the Tropics and Subtropics, Berlin, Sep. 19-21 1996; Humboldt-Universität zu Berlin; Schriftenreihe des Fachgebietes Obstbau Nr. 8, 68-77.

Venturieri, G.A., 1993: Cupuaçu: a Espécie, sua Cultura, Usos, e Processamento. Clube do cupu - Belém, 108 p.