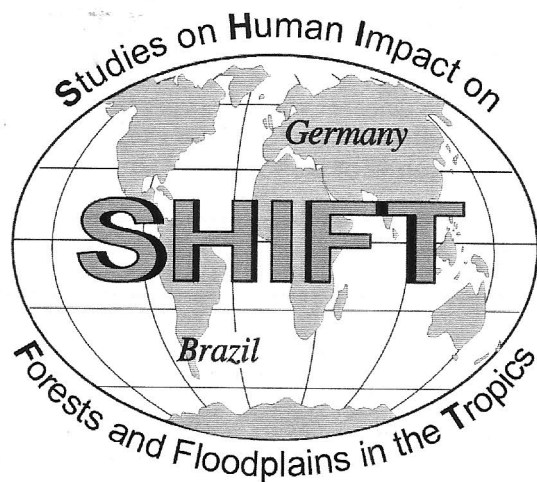


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## Production of agroforestry plants in polyculture systems in Western Amazon

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### ABSTRACT

In the Western Amazon, large land areas nowadays are degraded and/or abandoned, which were previously used for the establishment of monocultures. Agroforestry systems appear to be a good alternative to occupy these areas. In this work, mixed cropping systems involving fertilizer input (30 % and 100% of the recommended fertilization) and inoculation with VA-mycorrhizal fungi (absence and presence) were tested on a former experimental rubber plantation. The experimental area was divided into five blocks with eighteen plots each to test four mixed cropping systems (S1. Rubber, cupuaçu, peach palm and papaya; S2. cupuaçu, peachpalm, brazil nut, urucum and manioc; S3. Rubber, cupuaçu, coconut, orange, paricá, manioc, beans and maize; S4. rubber, paricá, mahogany and andiroba) and four conventional monocultures (rubber, cupuaçu, peachpalm and orange). The plants inoculated with VA-mycorrhizal fungi showed higher growth rates in the nursery, and higher survival rates after planting out. However, the possible beneficial effects of mycorrhizal fungi were not detected in the field. Except cupuaçu and peach palm, all species presented a higher initial plant development and production in the treatment with more fertilizer compared to those with lower fertilization.

### RESUMO

Na Amazônia Ocidental brasileira existem grandes extensões de áreas degradadas e /ou abandonadas, após terem sido utilizadas para fins agrícolas como monocultivos, pastagem ou agricultura itinerante. Os sistemas agroflorestais tem sido apontados como uma alternativa para a recuperação da capacidade produtiva destas áreas. Neste trabalho, diferentes sistemas de policultivo, implantados numa área de seringal abandonado, são testados com a utilização de fertilizantes (30% e 100% da adubação recomendada para cada espécie) e de fungos micorrízicos vesicular-arbuscular (presença e ausência). A área experimental foi dividida em 5 blocos ao acaso, com 18 parcelas cada, onde são avaliados 4 sistemas de policultivo (S1. seringueira, cupuaçu, pupunha e mamão; S2. cupuaçu, pupunha, castanha-do-brasil, urucum e mandioca; S3. seringueira, cupuaçu, coco, laranja, mandioca, paricá, feijão e milho; S4. seringueira, paricá, mogno e andiroba) e 4 monocultivos convencionais (seringueira, cupuaçu, pupunha e laranja). As plantas das espécies inoculadas com esporos de fungos micorrízicos vesicular-arbuscular (FMVA) apresentaram melhor desenvolvimento na etapa de viveiro e menores índices de mortalidade no campo após o transplante.

Com exceção da pupunha e do cupuaçu, as plantas das outras espécies que foram submetidas ao tratamento 100% de adubação, apresentaram desenvolvimento e produção inicial significativamente maior que àquelas submetidas ao nível de 30% de adubação.

## ZUSAMMENFASSUNG

In Westamazonien existieren große degradierte und/ oder aufgelassene Flächen, die vormals zum Anbau von Monokulturen genutzt wurden. Agroforstsysteme könnten eine gute Möglichkeit darstellen, dieses Land wieder einer Nutzung zuzuführen. In vorliegendem Artikel werden Untersuchungen mit Pflanzsystemen vorgestellt, die unterschiedlich gedüngt (30 % bzw. 100 % empfohlene Düngermenge) und teilweise mit VA-Mykorrhiza inokuliert wurden. Die Anlage der Experimentalflächen, unterteilt in fünf Blöcke mit jeweils 18 Parzellen, erfolgte auf einer ehemaligen Kautschukplantage und umfaßt vier unterschiedliche Mischkultursysteme (S1. Kautschuk, Paricá, Mahagoni und Andiroba; S2. Cupuaçu, Pfirsichpalme, Paranaß, Urucum und Maniok; S3. Kautschuk, Cupuaçu, Kokosnuß, Orange, Papaya, Maniok, Bohne und Mais; S4. Kautschuk, Papaya, Mahagoni und Andiroba) sowie vier konventionelle Monokulturen (Kautschuk, Cupuaçu, Pfirsichpalme und Orange). Die mit VA-Mykorrhiza inokulierten Pflanzen zeigten größere Wachstumsraten in der Vorkultur sowie höhere Überlebensraten nach dem Auspflanzen ins Feld. Mit Ausnahme von Cupuaçu und Pfirsichpalme führte die höhere Düngenge bei allen Spezies zu einer signifikanten Steigerung in Pflanzenentwicklung und Produktion.

## INTRODUCTION

The rainforest in the Brazilian Amazon basin is the last and the largest primeval tropical forest area in the world. According to Fearnside (1989) 415,200 km<sup>2</sup> of native forest were transformed in other forms of land use, which showed to be non sustainable in ecological, economic, and social aspects. Today, the greater part of this land has been abandoned, occupied by fallow field and degraded pastures. However, there is an estimate that about 500,00 families practice shifting cultivation in the Amazon, it means that they continue clearing new areas to plant subsistence crops. Reactivating the use of these fallow lying agricultural areas by stable, long lasting, profitable new areas of primary rainforest is of high importance for an agricultural management concept in Amazonia.

The real solution of the agricultural problems can only be found in an agroforestry system of selected, perennial plants. They give the possibility to build up conditions similar to those which exist in the primary forest. The function of perennial trees as reservoirs for nutrients and their role in the recycling of biomass in complex systems was demonstrated often (Burger 1986, Schubart 1977, Sioli 1994).

In this paper is described the research on the agroforestry systems development which are ecologically, socially and economically viable for the humid tropics by rising the productivity of these areas and, consequently, by using the areas for a long period of time. This would reduce the clearing and burning of primary forests and the rural-to-urban-migration.

## MATERIAL AND METHODS

The details on localization of the field trial, planted crops, plantation system and implemented test variants, experimental area and layout of the field test was described in Lieberei et al. (1993).

Fourteen species of useful plants were planted in the experimental field, in following four different agroforestry systems: S1. (rubber, cupuaçu, peach palm and papaya; S2. cupuaçu, peachpalm, brazil nut, urucum and manioc; S3. Rubber, cupuaçu, coconut, orange, manioc, beans and maize; S4. rubber, paricá, mahogany and andiroba) and four conventional monocultures (rubber, cupuaçu, peachpalm and orange) are to be compared in the field trial. In systems 1-3,1 plants inoculated with mycorrhizal fungi (VAMF) are compared to control plants. The fungi were applied to all plants cultivated in system 4, but not to the monocultures. The fertilization variants included 30% and 100% of the recommended dose of fertilizer for the respective species.

## RESULTS

### Reaction of useful plants to inoculation with VAMF in nursery conditions and in the field.

The Percentage of the VAMF colonization under nursery conditions in roots of urucum, papaya and paricá was about 50% and in roots of mahogany 35%. The roots of cupuaçu, coconut, peach palm, rubber tree, brazil nut and andiroba had only a low colonization. Inoculated with VAMF, all species showed a positive growing response independent to the percentage of colonization. After inoculation with VAMF the initial growing was about 70% in papaya, 36 % in mahogany and 28 % in andiroba. The low colonization in roots of some species like rubber tree, cupuaçu and Brazil nut was caused by difficulties of VAMF to colonize the roots of these species (Idczak 1996). The radicular system of these species has only a low density of radicells. The plants losses during the preparation and establishing success of a recultivation process can be economically decisive for the success of recultivation project. Transfer of the plants into the field and planting procedures often give rise to additional plant losses. No plant dies during the breeding time. But generally the species with low VAMF colonization in the roots suffered more stress soon after the transplantation of the young plants into the experimental area and, consequently, had greater loss because of the death of plants. The mortality of young rubber trees without VAMF inoculation and a fertilization of the recommended 100 % was 25 %. In general the lowest losses of useful plants were obtained with 30 % of fertilizer with inoculation of the plants with mycorrhizal fungi.

The level of roots colonization of the cultivated useful plants by VAMF in field condition depend of the management and treatment (monoculture, agroforestry systems, with or without inoculation of VAMF, quantity of applied fertilizer): The rubber tree, Brazil nut and paricá have not been analyzed as it was not possible to collect root samples without heavy disturbance of the trees. Cupuaçu, peach palm and coconut, which showed no or only low concentration of VAMF at the time of planting into the field, also hardly developed a mycorrhizal later on.

In agroforestry systems with two level of fertilizer treatments the application of only 30 % of the recommended amount of fertilizer generally resulted in higher levels of root colonization by VAMF than the 100 % treatment. Mycorrhization of orange grown in agroforestry systems was better than in monoculture. Differences in the root colonization between plants inoculated and not inoculated with VAMF which occurred in the nursery, did not continue in the field. This might be due to the colonization of non-inoculated plants by VAMF in the field soil.

### **Development and production of single species of the useful plants under field conditions**

Under field conditions, only the maize and the papaya showed a response to VAMF inoculation. In the order crops no significant response in the growth were found when the plants were inoculated with VAMF. There were significant differences in the fertilization levels tested. Table 1 shows data of perennial crops related to growth and/or production the fourth year after planted in the field.

**Manioc:** For manioc, significant difference in production between the two levels of fertilization was observed. The production on the „30 % fertilization level“ was 6910 kg/ha, on the „100 % fertilization level“ 8833 kg/ha.

**Corn:** In corn, significant differences of production were observed regarding to the level of fertilization (556 kg/ha for 30 % and 881 kg/ha for 100 % fertilizer level). The mean values of the plants inoculated by VAMF tend to be higher than those not inoculated (e.g. 604 kg/ha for +VAMF and 556 kg/ha for -VAMF in the plots „30 % fertilizer“).

**Papaya:** Being a crop of rapid growth and development, papaya showed some statistically significant differences with regard to the treatment groups. An important factor for growth is fertilization. The fruit production in the treatment group „30 % fertilization-VAMF“ was 569 kg/ha, where in „100 %-VAMF“ the production raised to 1862 kg/ha. Though not being statistically significant, in the „30 % fertilization level“ papaya gained in the 2. and 3. year of growth, within 22 month, 559 kg/ha in the „-VAMF“ and 971 kg/ha in the „+VAMF“ treatment. This result undoubtedly has to be valued as a success due to mycorrhizal fungi application.

**Cupuaçu:** The plants show mean values in production fruits slightly advanced in treatment with „100 % fertilization level“ than in the „30 %“. The production in the system 1 was significantly better than in system 2 and 3. Cupuaçu shows production statistically significant in agroforestry system when compared with monoculture.

**Peach palm:** The results give evidence that peach palm develops slightly advanced in treatment with „100 % fertilization level“ than in the „30 %“. The production in the system 1 was slightly advanced than in system 2. Moreover, peach palm shows a better production in agroforestry system than in monoculture.

**Coconut and urucum:** These species show mean values in production significantly better in treatment with „100 % fertilization level“ than in the „30 %“).

**Rubber tree and orange:** These useful plants show mean values in growth parameter slightly advanced in treatment with „100 % fertilization level“ than in the „30 %“. In the agroforestry systems the performance is better than in monoculture for both species.

**Brazil nut and paricá:** These species show mean values in growth slightly advanced in treatments with „100 % fertilization level“ than in the „30 %“.

**Mahogany and andiroba:** These species were planted only in system 4, where the secondary vegetation could regenerate and only the Plantation lines were cleaned. The plants were inoculated with VAMF and got 30 % of the recommended Fertilizer. The growing was hindered by the concurrence with the „capoeira“ and the high incidence of *Hipsipilla grandella*, a pest which attacks these plants on the point of growing.

**Incidence of diseases and pest**

Until now do not have significant differences of the incidence of diseases and pests between the agroforestry systems and the monocultures.

The following pathogens occurred: *Crinipellis pernicioso* and *Corticium salmonicolor* on cupuaçu; *Phytophthora* sp., *Septobasidium pseudopedicilatum*, *S. sacardium* and *C. salmonicolor* on orange tree; *Corticium penicillatum* on coconut palms and a disease yet not described on Brazil nut. *C. pernicioso* has been controlled by periodic pruning and *Phytophthora* sp. by preventive painting of the trunk with copper-based fungicides in the dry season. The other diseases were controlled by taking out affected parts.

With regard to pests, in mahogany, plant death has been occurred due to an attack by an unidentified woodborer of the roots and *Hipsiphilla grandella* in the shoots. In orange trees, apart from plant lice (*Toxoptera* sp.), cochineal insects have also frequently been observed, *Sibine nesea* and *Crinocerus sanctus*. In Brazil nut trees, *Hybolabus amazonicus* damages the epidermis of the leaves reducing the leaf area, impairing the development of the plant.

Fungicides and pesticides have been used as little as possible. Until now there was no difference in the intensities of diseases and pests between polyculture systems and monoculture systems, but intensities of diseases and pests were much lower compared to farmland in the region.

**Table 1:** Quality valuation of perennial plants development in the four treatment groups and in the plantation systems. Basis of valuation = cupuaçu, coconut, orange, peach palm and urucúm = production data; all other plant species = biometric data (plant heights, diameter of trunk).

	Fertilization levels		Plantation systems	
	30 %	100 %	Monoculture	Agroforestry
Rubber tree		○		○
Cupuaçu		○		●
Peach palm		○		○
Orange		○		○
Urucum		●		
Coconut		●		
Brazil nut		○		
Paricá		○		

Development and/or production in the treatment group/plantation system:

○ = slightly advanced

● = significantly different

## DISCUSSION

The obtained results show that under nursery conditions the use of VAMF was favorable for the development of the seedlings and young plants. The VAMF can be used in commercial measure to reduce both, the time until production of young plants and the quantity of fertilizer. An other important factor is the greater resistance to stress of mycorrhizal treated plants during the transplantation into the field and, consequently, the lower mortality of plants during the installation in the plantation. However, the colonization level of VAMF in the roots of inoculated and not inoculated plants does not differ one year after the installation of the plants in the field. There are no evident effects of VAMF to further growing and/or production of the plants. The fact that the plants show a significant response under nursery conditions and during the transplantation time proves that an adequate selection of VAMF could render better results, that is, the selection of native fungi from the forest or from the experimental area, probably, increasing the managerial sustainability of the VAMF in the field (Feldmann et al. 1995). The effective use of VAMF on a commercial scale in field conditions depends on biological studies of VAMF populations, the interrelationships between isolated VAMF and their effects on the plant. The use of VAMF in the production of seedling, in nursery conditions, appears to be economically viable.

The results show that the fertilization is a major requirement for the type of soil abundant in the experimental site („clayish yellow latosol“), but they revealed as well a need to carry on optimizing the dose and composition of fertilizer for the useful plant species under controlled conditions. Inoculating the useful plants with mycorrhizal fungi spores can be seen as a partial success, especially in the case of papaya. The results are promising and encouraging for more field studies on mycorrhizal research.

The reasons for the fact that there are only few significant differences in growth or yield parameters between the treatment groups, are to be sought in the heterogeneity of the site conditions relatively to the micro climate, the existent topographic gradients, the soil fertility (Taveres et al. 1993) and the existence of an ecological gradient advancing from block A to E (Preisinger et al. 1994).

The agroforestry systems for the Amazonia region provide better conditions for the development of useful plants than the monoculture which has been conducted according to common practice. The plantation of annual and perennial cultures permits the use of only one area for several years without cutting new areas, in case of the rubber tree until 25 years. The use of fertilizer and biological agents like VAMF, which can improve the physical and chemical soil conditions, allow the recultivation of cleared and abandoned sites with great economical returns. This reduce the „slash and burn“ agriculture, as practiced by the local small holders, the environmental destruction and the rural exodus.

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